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ASPHALTUM FOR A MODERN STREET.

By S. F. PECKHAM.

ASPHALTUM is the solid form of bitumen, as it occurs in nature. It has been known to man from prehistoric times. The word is said to be derived from *ἀ* privative, and *σφάλλο* 'I cause to slip.' It, therefore, signifies a substance that prevents one from slipping, and was applied to the solid forms of bitumen that soften in the sun. This substance was not rare in so-called Bible lands, embracing the Valley of the Euphrates, the table lands of Mesopotamia and the Valley of the Jordan. It was of frequent occurrence along the shores of the Dead Sea, and was gathered and sold in the caravan trade that passed through the land of Moab and Petrea into Egypt, where it was used in the preparation of mummies.

During the Middle Ages, asphaltum appears to have found but few uses, and is seldom mentioned. The words asphaltum, petroleum and naphtha appear to have been used with different meanings, and also interchangeably or synonymously; yet the words were generally used to signify a thing that was located and defined by further description, so that the bitumen of the Dead Sea was recognized as asphaltum or solid bitumen.

Within the present century, however, both words and definitions have been more exact. As other and slightly differing material was obtained that in some respects resembled coal, it was claimed that some of the deposits of bitumen were beds of coal, and this claim led, about 1850, to important litigation, in which, as experts, scientific men gave very conflicting testimony, one party claiming that the material of certain deposits was asphaltum, and the other that it was coal. It was finally decided that the material—the albertite of New Brunswick—was not coal, and, therefore, did not belong to the Crown. At about this time a deposit occurring in West Virginia, since known as Grahamite, which, in appearance, is much more like splint coal than albertite,

attracted attention. There were veins of material in Cuba that were also included in the argument, Coal vs. Asphalt.

The late Dr. T. Sterry Hunt, as long ago as 1863, separated asphaltum from pyrobituminous minerals, or minerals that on being heated to destructive distillation yield products that resemble bitumens. These pyrobituminous coals, schists and shales are nearly as insoluble in the solvents of bitumen, viz., ethyl ether, chloroform, benzole, etc., as they are in distilled water; hence, Dr. Hunt made the action of these solvents the test of the two classes of substances. All true bitumens are miscible with or almost wholly soluble in chloroform, a test that clearly separates them from pyrobituminous minerals. So-called 'asphaltic coals' are not coals at all, but are geologically old asphaltums.

Besides the asphaltums, almost wholly soluble in chloroform, there are a large number of minerals that consist only in part of true bitumens. These are found as beds of sedimentary or crystalline rock, often of immense extent and thickness, impregnated with bitumens of varying consistency and quality, sometimes very soft and seldom quite solid after being separated from the rock. In some instances the bitumen appears to be convertible into asphaltum, and in others not. The French writers have called these rocks 'asphalte,' but, unfortunately, they have also called asphaltum by the same name, as if the things were identical and the words synonymous. Among English writers no uniform custom prevails, but German authors use generally the French word, at the same time calling asphaltum 'Erdpech' or 'Glanzpech.' I think it would promote clearness of expression if this word 'asphalte' were uniformly introduced into all modern languages to designate those bituminous rocks, with the qualifying words, siliceous, calcareous or argillaceous, added as required.

The so-called Trinidad pitch, as it is found in and around the lake, on the island of Trinidad, is a mixture of bitumen, water, mineral and vegetable matter, the whole inflated with gas. When removed from the deposit, most of the water dries out, the gas escapes, the mass changes in color from brown to blue-black, becoming brittle, and at the same time more or less sticky as it loses water. At a rough estimate, about 25 per cent. of the natural cheese-pitch is bitumen.

Various theories have been formulated by scientific men to account for the origin of asphaltum and other forms of bitumen. By some it is thought that complex chemical changes take place between water, carbonate of lime and iron, and other elements that are supposed to exist in the free state or in combination with carbon as carbides, at great depths from the surface. When they have been formed they are supposed to rise towards the surface with steam and water. This is called the 'chemical' theory. Others think that organic animal and vegetable matter that has been buried in strata near the surface of the

earth has been converted by a process of partial decay into bitumen. This is called the 'indigenous' theory. Others think that the natural heat of the crust of the earth generated by pressure and, perhaps, other causes, has distilled bitumens from pyrobituminous minerals, and, in some instances, from coal, and they have penetrated the surrounding and overlying porous formations, often filling crevices and forming veins, when the pressure becomes sufficient to rupture the overlying formations. I am inclined to think this latter theory, of 'distillation,' will best account for all the varying conditions under which the various forms of bitumen occur.

Bitumens occur in all periods of the geological history of the earth's crust, but are mainly confined to the formations anterior to the coal period and to the later formations of the tertiary. While asphaltum is found in some of the oldest formations, the greater number of the deposits of solid bitumen and bituminous rocks occur in the more recent formations.

In order to show graphically the relations of the pyrobituminous minerals to the various forms of bitumen, I have arranged the following table, which represents the development of our present knowledge of these substances from the time when M. Léon Malo first published a similar table about forty years ago:

Mineral Substances of Organic Origin.	Bitumens.	Coals.	Anthracite, North America, Wales, Belgium, France, etc.
			Pyro-Bituminous. (Splint, Cannel, Peat, Shales, Schists.) — Found all over the world; yielding bituminous substances by destructive distillation, shales of Autun and Mansfeld, Bog-head mineral, Wollongonite, etc.
		Natural gas.—In the United States, Indiana, Ohio, Pennsylvania, etc. Russia, France, China, etc.	
		Natural naphtha.—Persia, Cuba and generally in petroleum regions.	
		Petroleum.—Central United States, California, Peru, Cuba, Russia, Borneo, Java, etc.	
		Maltha.—Persia, Albania, Texas, California, Peru, Trinidad, Mexico, Cuba, etc.	
		Asphaltum.	North America.—New Brunswick, West Virginia, Utah, California, Mexico.
			Central America.—Cuba and other West Indies.
			South America.—Trinidad, Peru, Venezuela.
			Europe.—Caucasia, France, Dalmatia, Italy, Germany.
			Asia.—Asia Minor, Persia, Euphrates Valley.
			Africa.—Egypt and other localities.
		Asphaltes (Bituminous Rocks).	North America.—Kentucky, Indian Territory, California, Utah, Texas, Athabasca River.
			Central America.—Mexico and Cuba.
			South America.—Island of Trinidad, Venezuela.
			Europe.—Germany, France, Italy, Russia, Austria, etc.
			Asia.—Asia Minor, Palestine, Persia, China.
			Africa.—Egypt and other localities.

While it might be interesting to describe in detail all the minerals mentioned in this table, we are at present concerned with only two, viz., asphaltums and asphaltes. Again, while it might be interesting to describe asphaltums and asphaltes from all the many localities in which they occur, we are at present concerned only with those in use in street paving, and particularly those in use in the United States.

It is said that the idea of constructing a roadway of asphalte was first suggested by the observation that lumps of asphalte that have dropped from carts upon a road, when trodden by animals and rolled beneath wheels, became compacted into a homogeneous and resisting surface. These observations were made in eastern France, in the valley of the Rhone, where very extensive deposits occur, extending into Switzerland. They were first brought into notice, about 1721, by Eirinis

FIG. 1. THE PITCH LAKE IN TRINIDAD AS IT APPEARED BEFORE 1890.

d'Erynys, a Greek physician, who published a pamphlet in which were described deposits of sand and limestone saturated with bitumen that he had discovered some years previously in the Val de Travers, Canton of Neufchâtel, Switzerland. He described also a bituminous distillate which he used in the treatment of disease. He compared the deposits to similar beds in the valley of Siddim, near Babylon. They were forgotten for nearly a century and then re-discovered.

By whom this material was first used in road building is unknown. Early in 1850, M. de Coulaine published a paper in the 'Annales des Ponts et Chausses,' in which he discussed the use of bitumen in road building as if it was an established industry. He states, without giving any date, that the first attempt to construct a street of bitumen in Paris was made upon the Place Louis XV., opposite the Church of Saint

Roch. This pavement was formed of fragments of quartz and of mastic of coal-tar, upon a bed of sandstone, the joints of which were filled with the mastic. These coal-tar streets, even with a concrete base, were not satisfactory, thus early establishing the undesirable qualities of coal-tar preparations in the construction of streets.

He states his preference for the asphaltes found at Seyssel, Val de Travers and Lobsan, which are composed principally of carbonate of lime and bitumen or sandstone and bitumen. As found in nature, these asphaltes consist either of chalk, sandstone or coarser gravel which have been filled to saturation with bitumen, which when extracted or separated from the mineral constituents of the rocks, is semi-fluid, resembling mineral tar. The deposits occur in beds between more dense and barren rock, and are mined out by running galleries and tunnels

FIG. 2. DIGGING AND REMOVING PITCH FROM THE LAKE PRIOR TO 1890.

into the hills that border the valleys, in a manner similar to the mining of coal in some sections of country.

Other deposits of similar material occur at Ragussa, in Sicily, and at Limmer, in Hanover. The Seyssel and Neufchâtel rocks are generally preferred for streets, as they contain more lime and less sand, and are also freer from sulphur compounds.

On the North American continent there are deposits of vast extent both of asphaltum and asphaltes. Generally speaking, asphaltum is not used in street construction; the deposits being either too pure, and hence too valuable for such uses, or, on the other hand, so impure as to be purified only at too great cost. As the asphalte is used in enormous quantities, freight becomes a very important consideration in the selection of the material used in any given locality. This item of cost has given

the deposit on the island of Trinidad very great importance as a source of supply for all the Atlantic Coast cities and even those as far west as Denver, while the Pacific Coast cities have been supplied from deposits in California, which to some extent have competed with Trinidad pitch, not only in the Mississippi Valley, but even in New York and other Eastern cities.

The deposits in Trinidad are comprised in the so-called lake and extensive masses outside of it that have either overflowed from the lake or have been derived from independent sources. In the aggregate the extent of the deposits can only be estimated, as their boundaries cannot be determined with any approach to accuracy. They amount, without any doubt, to several millions of tons.

While I have classed the Trinidad pitch with the asphaltes, it is really a unique substance. I have elsewhere called it 'Parianite,' from

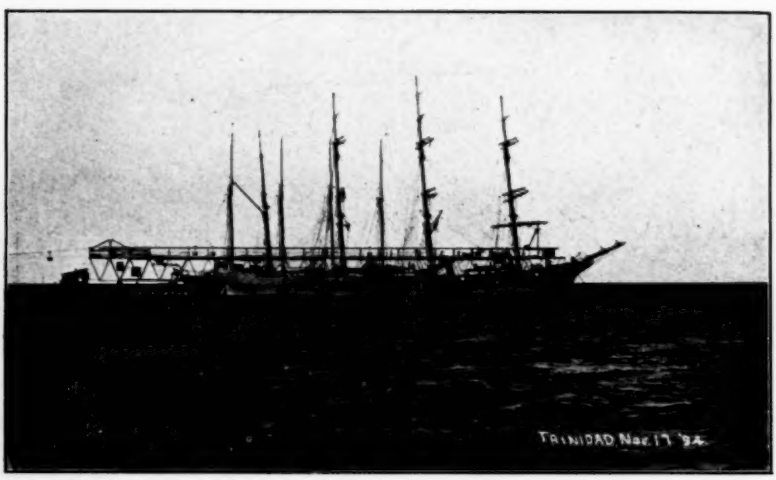

FIG. 3. LOADING SHIPS AT WHARF.

the beautiful bay of Paria, near the coast of which the deposit occurs. The lake is a lake only in name; the deposit, without doubt, filling the crater of an old mud volcano. As described for more than a century preceding 1890, it exhibited an expanse of about one hundred and fourteen acres, with a nearly circular outline, in which irregular areas of pitch are separated by smaller areas of water. Around the borders of the lake, vegetation, commencing at some distance from the edge, is rooted in the pitch itself, and, increasing in vigor as the border is approached, becomes upon the land a tropical jungle of canna and palms, perhaps thirty feet in height. In the center is a circle of islands that float on the pitch. The irregular water areas are many feet in depth, with nearly perpendicular sides, containing very transparent water that ap-

parently has its source in subterranean springs. The areas of pitch are of considerable extent, highest in the middle, but still nearly level and gently sloping on all sides to the precipitous edges of the water areas. These areas are being continually elevated in the center by rising gas, which, forcing up the center in huge bubbles, cause a continual ebullition of the plastic mass and a gradual transference of the material from the center towards the circumference, so that trunks and branches of trees submerged in the pitch come to the surface, rise, and after assuming a perpendicular position, are in time again submerged to an unknown depth. From the escaping gas the whole central portion of the lake is maintained in a constant motion that prevents vegetation

FIG. 4. TRAMWAY AND TRUCKS ON PITCH LAKE.

from taking root, and leaves the surface of the areas of pitch bare and of a blue-black color.

When the pitch is dug, a negro will drive a long, slender pick to the eye at a single blow, and, by using the handle as a lever, will break out a flake of pitch larger than he can lift. From less than an inch below the surface the pitch is of a brown color, saturated with water and filled with bubbles of gas. A broken mass will soon dry on the surface and melt, forming a pellicle that will enclose the wet mass for years and prevent the escape of the water. In this wet and porous condition it is called 'cheese pitch.' It is not sticky at all, as the water can be squeezed from it in the hand, as if it were a sponge.

Formerly the large lumps of this cheese pitch, as it was broken out, were transported to the beach in carts, but about 1893-4 a wharf was

constructed on the Bay of Paria, near the lake, and a trolley line and tramway, leading from the wharf up to and out upon the lake in a loop, by which the pitch since then has been transported direct from the surface of the lake to the vessel being loaded. Formerly the pitch was carried from the beach to ships lying in the bay in lighters, the shipping entailing a great deal of labor from repeated handling. Since the tramway was installed, the pitch is dug along the line of the tramway and thrown into iron buckets, resting on trucks that are propelled along the tramway by an endless cable. Great difficulty was encountered when the tramway was laid to prevent its sinking in the pitch, which, while hard enough on the surface to bear up a loaded team, will slowly engulf any

FIG. 5. A LOT OUTSIDE THE LAKE THAT HAS FILLED IN SIX MONTHS AFTER BEING EXCAVATED 20 FEET.

article of even moderate weight. This trouble was overcome by laying the tramway on a bed of the leaves of the Moriche palm, some of which are twenty-five feet in length. When the car-buckets are loaded they are run to the power-house in groups of three or four, where, after being weighed, they are transferred by an ingenious device from the trucks to a trolley that runs on an endless rope from the lake to the wharf, where the contents of the buckets are dumped into the hold of the ship-like coal. The plant will handle 500 tons a day in the manner described.

Immense quantities of the pitch lie outside the lake, and the pitch from these deposits, wherever worked, is still shipped by means of

lighters. The surface of the lake is 148 feet above the sea-level, and the pitch has flowed down to the sea from the lake in an immense stream that resembles a black glacier. Excavations made in this mass soon fill up again and all traces of them are in time obliterated, and buildings, the foundations of which are placed in or upon the pitch, are soon thrown out of perpendicular, from the unstable condition of the pitch, which appears to be moving or flowing towards the sea under a great pressure. These phenomena present the unique spectacle of a mass so solid as to be walked or driven over, and at the same time so plastic as to be in a state of unstable equilibrium, with constant ebullition from escape of gas and also in constant motion towards the sea.

Before the pitch is put to any use it is refined. In the operations attending its shipment and subsequent removal from the hold of the

FIG. 6. BARRELS OF ÉPUREE AT LA BRIA, TRINIDAD, AND PILES OF PITCH AWAITING SHIPMENT IN THE LIGHTERS NEAR SHORE.

ship, it has been very much broken up, and much of the gas has escaped with some of the water. In this condition it is put into enormous kettles, which are heated from above downward, and very slowly, until the contents of thirty tons or more are melted. The heat necessary to melt the pitch expels the water, the fragments of wood and other light impurities rise to the surface, and the heavy mineral matter, in large part, sinks to the bottom. The clean pitch between them is drawn off into barrels.

A more primitive method of refining the pitch is used at the island, where the pitch is boiled in old sugar kettles and skimmed, when the clean pitch is ladled into barrels and enters commerce as 'épurée.'

In the neighborhood of Trinidad, on the mainland of Venezuela, is another so-called Bermudez lake. It is found in a low savannah, extend-

ing between a range of mountains and the shore o fone of the estuaries that enter the northern part of the delta of the Orinoco from the Bay of Paria. The lake has an irregularly shaped surface, about one mile and a half by one mile in dimensions, giving an area of something less than 1,000 acres. This area is covered with rank grass and shrubs, from one to eight feet in height, with groves of large Moriche palms. There is no extended surface of clean pitch as at Trinidad; but instead, at certain points, soft pitch wells up as if from subterranean springs. As the general surface of the deposit is not more than two feet above the surrounding swamp, in the rainy season it is flooded, and at other times so low that any excavation will immediately fill with water.

Instead of being more than a hundred feet in depth as at Trinidad, this deposit is a shallow exudation from numerous springs, over a wide surface, from a mere coating to from seven to nine feet in depth, the average being perhaps four feet. The largest of the areas covered with soft pitch is not more than seven acres in extent. The soft material has become hardened in the sun at the edges, but at the center is too soft to walk upon, in this respect resembling many of the deposits of less extent in California. This pitch is also too soft to hold permanently the escaping gas, as at Trinidad, but when covered with water it rises in mushroom-like forms.

Some of these areas have been burned over, producing from the combustion of the vegetation and of the asphaltum itself an intense heat that has converted the bitumen into coke and glance pitch. When this crust of hardened material is removed, beneath it is found asphaltum that may be used for paving.

Under the classification that I have adopted, the bitumen of the Bermudez deposit is nearly pure asphaltum, which has been formed by the heat of the sun and by fire, from an exudation of maltha, or mineral tar, over a wide expanse, beneath the coke and other products of combustion, while here and there are masses of glance pitch, which are the result of less violent action of heat.

Many of the West India islands, from Trinidad around to Cuba, contain deposits of asphaltum. The most noted among them are the Munjack of Barbadoes and the asphaltum veins of Cuba. These, however, have not entered commerce, with the exception, perhaps, of the very pure asphaltum found in Cardenas harbor, which is obtained in limited quantities and is used in varnish-making. None of these are used in paving.

In Mexico there are very extensive deposits of asphaltum of great purity, but up to the present time they have not entered commerce.

In Texas, and extending into the Indian Territory, there are large deposits of both siliceous and calcareous asphaltes. In Uralde county, Texas, near Cline, to the west of San Antonio, on the Southern Pacific

Railroad, are very extensive deposits of coquina or shell limestone, filled with bitumen. As found, the material is very tough and difficult to break. When the bitumen is dissolved out with chloroform, there remains a mass of small shells, very light and porous, but with sufficient stability to form a rock. The shells contain from nine to thirteen per cent. of bitumen. While a large sum has been expended on a plant for extracting this bitumen, the enterprise has never proved a pecuniary success. In northern Texas, near the Red River, are extensive deposits of bituminous sand, which has been used locally for sidewalks with success. Across the Red River, near the Arbuckle Mountains, in the Chickasaw Nation, beds of bituminous sand occur of great extent. They extend across the country in anticlinal folds for miles in length. The material is not stone, as the sand falls into a powder as soon as the

FIG. 7. THE 'BIG SPRING' OF TAR, 30 FEET IN DIAMETER, UPPER OJAI, VENTURA COUNTY, CAL

bitumen is removed from it. When the material is broken into small pieces and placed in boiling water, the bitumen rises to the surface nearly free from sand, while the bulk of the sand sinks through the water clean. The bitumen thus obtained is of very superior quality for any purpose. Still farther north and east, near the town of Dougherty, several deposits occur. One is a mass of great extent of fragments of chert and limestone cemented together with bitumen. A mastic has been made by grinding this material. Another mass consists of a magnesian chalk, of carboniferous age, saturated with bitumen. Another is a mass of large shells filled with more than twenty per cent. of bitumen. Other deposits of loose sand occur in beds, saturated with ten per cent. of bitumen. These materials have been used separately and ground together for paving mixtures for street surfaces.

In Utah, upon the Uintah Indian reservation, are found veins of asphaltum of remarkable purity, to which the name 'Gilsonite' has been given. It has been found very useful for insulation and a great variety of purposes, but has only been used in combination with softer material for paving.

Among the coast ranges of California there are deposits of asphaltum and siliceous asphalte of vast extent. At Santa Cruz, to the east and west of Santa Barbara, near the coast near San Buena Ventura and Los Angeles, on the Ojai ranch, and at Asphalto, in Kern County, the principal ones are found. Those of commercial value are at the works of the Alcatraz Company, west of Santa Barbara, and near Asphalto. At the works of the Alcatraz Company the bitumen is dissolved in a

FIG. 8. ASPHALTUM GLACIER, KERN COUNTY, CAL.

solvent and conveyed through pipes some thirty miles to the coast, where the solvent is removed and the bitumen prepared for shipment.

At Asphalto, on the north side of the Coast range, in Kern County, the asphaltum occurs nearly pure in veins of great extent that have been mined to a depth of more than three hundred feet. From these statements it will be seen that the deposits of asphaltum and asphalte in the United States are of vast extent and variety.

While the bitumen in these different deposits in different parts of the world bears a generic relation, there are specific differences between the different varieties that render some of them more desirable for certain purposes than the others. The purest asphaltums are brilliant black, brittle solids that consist of compounds of carbon and hydrogen with small proportions of oxygen, sulphur and nitrogen. The latter

of these constituents are not always present and vary widely in amount when present, so that, from a chemical standpoint, the different asphaltums and the bitumens of the different asphaltes are very unlike substances. In the practical uses to which these substances are applied, the selection for any given purpose does not appear to depend upon difference of composition. The purest varieties are used for making fine varnishes and lacquers. Others are used for coarser varnishes that are baked on to iron and other surfaces. Others are applied, softened with solvents that evaporate. These substances find wide uses for insulating purposes, alone and in mixture with other materials.

The widest use to which they are applied is in street-paving surfaces, for which purpose vast quantities are used every year. It has been

FIG. 9. SHAFT ON ASPHALTUM VEIN NEAR ASPHALTO, FROM WHICH MASS WAS TAKEN WEIGHING 6,500 POUNDS.

found in practice that good streets and poor streets have been made from nearly all the different varieties of asphaltums and asphaltes that can be obtained in such quantity and at such a price as to render their use possible. The different results obtained appear to be due to causes external to the asphaltum or asphalte employed, such as the kind and quality of the materials with which they are mixed and the method, or lack of method, by which they are mixed. These conclusions appear to be warranted by a large number of experiments extending over many years, some of which have been very expensive for the municipalities making them.

THE EFFECT OF PHYSICAL AGENTS ON BACTERIAL LIFE.*

By Dr. ALLAN MACFADYEN,
THE JENNER INSTITUTE OF PREVENTIVE MEDICINE.

THE fact that life did not exist upon the earth at a remote period of time, the possibility of its present existence as well as the prospect of its ultimate extinction, can be traced to the operation of certain physical conditions. These physical conditions upon which the maintenance of life as a whole depends are in their main issues beyond the control of man. We can but study, predict and it may be utilize their effects for our benefit. Life in its individual manifestations is, therefore, conditioned by the physical environment in which it is placed. Life rests on a physical basis, and the main springs of its energies are derived from a larger world outside itself. If these conditions, physical or chemical, are favorable, the functions of life proceed; if unfavorable, they cease—and death ultimately ensues. These factors have been studied and their effects utilized to conserve health or to prevent disease. It is our purpose this evening to study some of the purely physical factors, not in their direct bearing on man, but in relation to much lower forms in the scale of life—forms which constitute in number a family far exceeding that of the human species, and of which we may produce at will in a test-tube, within a few hours, a population equal to that of London. These lowly forms of life—the bacteria—belong to the vegetable kingdom, and each individual is represented by a simple cell.

These forms of life are ubiquitous in the soil, air and water, and are likewise to be met with in intimate association with plants and animals, whose tissues they may likewise invade with injurious or deadly effects. Their study is commonly termed bacteriology—a term frequently regarded as synonymous with a branch of purely medical investigation. It would be a mistake, however, to suppose that bacteriology is solely concerned with the study of the germs of disease. The dangerous microbes are in a hopeless minority in comparison with the number of those which are continually performing varied and most useful functions in the economy of nature. Their wide importance is due to the fact that they insure the resolution and redistribution of dead and effete organic matter, which if allowed to accumulate would speedily render life impossible on the surface of the earth. If medicine ceased to regard the bacteria, their study would

* Lecture before the Royal Institution of Great Britain.

still remain of primary importance in relation to many industrial processes in which they play a vital part. It will be seen, therefore, that their biology presents many points of interest to scientific workers generally. Their study as factors that ultimately concern us really began with Pasteur's researches upon fermentation. The subject of this evening's discourse, the effect of physical agents on bacterial life, is important not merely as a purely biological question, though this phase is of considerable interest, but also on account of the facts I have already indicated, viz., that micro-organisms fulfil such an important function in the processes of nature, in industrial operations and in connection with the health of man and animals. It depends largely on the physical conditions to be met with in nature whether they die or remain inactive. Further, the conditions favoring one organism may be fatal to another, or an adaptability may be brought about to unusual conditions for their life. To the technologist the effect of physical agents in this respect is of importance, as a knowledge of their mode of action will guide him to the means to be employed for utilizing the micro-organisms to the best advantage in processes of fermentation. The subject is of peculiar interest to those who are engaged in combating disease, as a knowledge of the physical agents that favor or retard bacterial life will furnish indications for the preventive measures to be adopted. With a suitable soil and an adequate temperature the propagation of bacteria proceeds with great rapidity. If the primary conditions of soil and an adequate temperature are not present, the organisms will not multiply, they remain quiescent or they die. The surface layers of the soil harbor the vast majority of the bacteria, and constitute the great storehouse in nature for these forms of life. They lessen in number in the deeper layers of the soil, and few or none are to be met with at a depth of 8-10 feet. As a matter of fact, the soil is a most efficient bacterial filter, and the majority of the bacteria are retained in its surface layers and are to be met with there. In the surface soil, most bacteria find the necessary physical conditions for their growth, and may be said to exist there under natural conditions. It is in the surface soil that their main scavenging functions are performed. In the deeper layers, the absence of air and the temperature conditions prove inimical to most forms.

Amongst pathogenic bacteria the organisms of lockjaw and of malignant œdema appear to be eminently inhabitants of the soil. As an indication of the richness of the surface soil in bacteria, I may mention that 1 gramme of surface soil may contain from several hundred thousand to as many as several millions of bacteria. The air is poorest in bacteria. The favoring physical conditions to be met with in the soil are not present in the air. Though bacteria are to be met with in the air, they are not multiplying forms, as is the case in

the soil. The majority to be met with in air are derived from the soil. Their number lessens when the surface soil is moist, and it increases as the surface soil dries. In a dry season the number of air organisms will tend to increase.

Town air contains more bacteria than country air, whilst they become few and tend to disappear at high levels and on the sea. A shower of rain purifies the air greatly of bacteria. The organisms being, as I stated, mainly derived from the surface of the ground, their number mainly depends on the physical condition of the soil, and this depends on the weather. Bacteria cannot pass independently to the air; they are forcibly transferred to it with dust from various surfaces. The relative bacterial purity of the atmosphere is mainly, therefore, a question of dust. Even when found floating about in the air the bacteria are to be met with in much greater number in the dust that settles on exposed surfaces, e. g., floors, carpets, clothes and furniture. Through a process of sedimentation the lower layers of the air become richer in dust and bacteria, and any disturbance of dust will increase the number of bacteria in the air.

The simple act of breathing does not disseminate disease germs from a patient; it requires an act of coughing to carry them into the air with minute particles of moisture. From the earliest times great weight has been laid upon the danger of infection through air-borne contagia, and with the introduction of antiseptic surgery the endeavor was made to lessen this danger as much as possible by means of the carbolic spray, etc. In the same connection numerous bacteriological examinations of air have been made, with the view of arriving at results of hygienic value. The average number of micro-organisms present in the air is 500-1000 per 1000 liters; of this number only 100-200 are bacteria, and they are almost entirely harmless forms. The organisms of suppuration have been detected in the air, and the tubercle bacillus in the dust adhering to the walls of rooms. Investigation has not, however, proved air to be one of the important channels of infection. The bactericidal action of sunlight, desiccation and the diluting action of the atmosphere on noxious substances will always greatly lessen the risk of direct aerial infection.

The physical agents that promote the passage of bacteria into the air are inimical to their vitality. Thus, the majority pass into the air not from moist but from dry surfaces, and the preliminary drying is injurious to a large number of bacteria. It follows that if the air is rendered dust-free, it is practically deprived of all the organisms it may contain. As regards enclosed spaces, the stilling of dust and more especially the disinfection of surfaces liable to breed dust or

to harbor bacteria are more important points than air disinfection, and this fact has been recognized in modern surgery. In an investigation, in conjunction with Mr. Lunt, an estimation was arrived at of the ratio existing between the number of dust particles and bacteria in the air. We used Dr. Aitken's dust-counter, which not only renders the air dust particles visible, but gives a means of counting them in a sample of air. In an open suburb of London we found 20,000 dust particles in 1 cubic centimeter of air; in a yard in the center of London about 500,000. The dust contamination we found to be about 900 per cent. greater in the center of London than in a quiet suburb. In the open air of London there was on an average just one organism to every 38,300,000 dust particles present in the air, and in the air of a room, amongst 184,000,000 dust particles, only one organism could be detected.

These figures illustrate forcibly the poverty of the air in microorganisms, even when very dusty, and likewise the enormous dilution they undergo in the atmosphere. Their continued existence is rendered difficult through the influence of desiccation and sunlight. Desiccation is one of nature's favorite methods for getting rid of bacteria. Moisture is necessary for their development and their vital processes, and constitutes about 80 per cent. of their cell-substance. When moisture is withdrawn most bacterial cells, unless they produce resistant forms of the nature of spores, quickly succumb. The organism of cholera air-dried in a thin film dies in three hours. The organisms of diphtheria, typhoid fever and tuberculosis show more resistance, but die in a few weeks or months.

Dust containing tubercle bacilli may be carried about by air currents, and the bacilli in this way transferred from an affected to a healthy individual. It may, however, be said that drying attenuates and kills most of these forms of life in a comparatively short time. The spores of certain bacteria may, on the other hand, live for many years in a dried condition, e. g., the spores of anthrax bacilli, which are so infective for cattle and also for man (wool-sorters' disease). Fortunately few pathogenic bacteria possess spores, and, therefore, drying by checking and destroying their life is a physical agent that plays an important rôle in the elimination of infectious diseases. This process is aided by the marked bactericidal action of *sunlight*. Sunlight, which has a remarkable fostering influence on higher plant life, does not exercise the same influence on the bacteria. With few exceptions we must grow them in the dark in order to obtain successful cultures; and a sure way of losing our cultures is to leave them exposed to the light of day. Direct sunlight is the most deadly agent, and kills a large number of organisms in the short space of one to two hours; direct sunlight proves fatal to the typhoid bacillus in

half an hour to two hours; in the diphtheria bacillus in half an hour to one hour, and to the tubercle bacillus in a few minutes to several hours. Even anthrax spores are killed by direct light in three and a half hours. Diffuse light is also injurious, though its action is slower. By exposing pigment-producing bacteria to sunlight colorless varieties can be obtained, and virulent bacteria so weakened that they will no longer produce infection. The germicidal action of the sun's rays is most marked at the blue end of the spectrum, at the red end there is little or no germicidal action. It is evident that the continuous daily action of the *sun* along with *desiccation* are important physical agents in arresting the further development of the disease germs that are expelled from the body.

It has been shown that sunlight has an important effect in the spontaneous purification of rivers. It is a well-known fact that a river, despite contamination at a given point, may show little or no evidence of this contamination at a point further down in its course. Buchner added to water 100,000 colon bacilli per cubic centimeter, and found that all were dead after one hour's exposure to sunlight. He also found that in a clear lake the bactericidal action of sunlight extended to a depth of about six feet. Sunlight must, therefore, be taken into account as an agent in the purification of waters, in addition to sedimentation, oxidation and the action of algæ.

Air or the oxygen it contains has important and opposite effects on the life of bacteria. In 1861, Pasteur described an organism in connection with the butyric acid fermentation which would only grow in the absence of free oxygen. And since then a number of bacteria, showing a like property, have been isolated and described. They are termed anaerobic bacteria, as their growth is hindered or stopped in the presence of air. The majority of the bacteria, however, are aerobic organisms, inasmuch as their growth is dependent upon a free supply of oxygen. There is likewise an intermediate group of organisms, which show an adaptability to either of these conditions, being able to develop with or without free access to oxygen. Preeminent types of this group are to be met with in the digestive tract of animals, and the majority of disease-producing bacteria belong to this adaptive class. When a pigment-producing organism is grown without free oxygen its pigment production is almost always stopped. For anaerobic forms N and H_2 give the best atmosphere for their growth, whilst CO_2 is not favorable, and may be positively injurious, as, e. g., in the case of the cholera organism.

The physical conditions favoring the presence and multiplication of bacteria in water under natural conditions are a low altitude, warmth, abundance of organic matter and a sluggish or stagnant condition of the water. As regards water-borne infectious diseases, such

as typhoid or cholera, their transmission to man by water may be excluded by simple boiling or by an adequate filtration. The freezing of water, whilst stopping the further multiplication of organisms, may conserve the life of disease germs by eliminating the destructive action of commoner competitive forms. Thus the typhoid bacillus may remain frozen in ice for some months without injury. Employment of ordinary cold is not, therefore, a protection against dangerous disease germs.

As regards *electricity*, there is little or no evidence of its direct action on bacterial life, the effects produced appear to be of an indirect character, due to the development of heat or to the products of electrolysis.

Ozone is a powerful disinfectant, and its introduction into polluted water has a most marked purifying effect. The positive effects of the electric current may, therefore, be traced to the action of the chemical products and of heat. I am not aware that any direct action of the X-rays on bacteria has up to the present been definitely proved.

Mechanical agitation, if slight, may favor, and if excessive, may hinder bacterial development. Violent shaking or concussion may not necessarily prove fatal so long as no mechanical lesion of the bacteria is brought about. If, however, substances likely to produce triturating effects are introduced, a disintegration and death of the cells follows. Thus Rowland, by a very rapid shaking of tubercle bacilli in a steel tube, with quartz sand and hard steel balls, produced their complete disintegration in ten minutes.

Bacteria appear to be very resistant to the action of *pressure*. At 300-450 atmospheres putrefaction still takes place, and at 600 atmospheres the virulence of the anthrax bacillus remained unimpaired. Of the physical agents that affect bacterial life, temperature is the most important. Temperature profoundly influences the activity of bacteria. It may favor or hinder their growth, or it may put an end to their life. If we regard temperature in the first instance as a favoring agent, very striking differences are to be noted. The bacteria show a most remarkable range of temperature under which their growth is possible, extending from zero to 70° C. If we begin at the bottom of the scale we find organisms in the water and in soil that are capable of growth and development at zero. Amongst these are certain species of phosphorescent bacteria, which continue to emit light even at this low temperature. At the Jenner Institute we have met with organisms growing and developing at 34-40° F. The vast majority of interest to us find, however, the best conditions for their growth from 15° up to 37° C. Each species has a minimum, an optimum and a maximum temperature at which it will develop. It is important in studying any given

species that the optimum temperature for their development be ascertained, and that this temperature be maintained. In this respect we can distinguish three broad groups. The first group includes those for which the optimum temperature is from 15-20° C. The second group includes the parasitic forms, viz., those which grow in the living body, and for which the optimum temperature is at blood heat, viz., 37° C. We have a third group, for which the optimum temperature lies as high as 50-55° C. On this account this latter group has been termed thermophilic on account of its growth at such abnormally high temperatures—temperatures which are fatal to other forms of life. They have been the subject of personal investigation in conjunction with Dr. Blaxall. We found that there existed in nature an extensive group of such organisms to which the term thermophilic bacteria was applicable. Their growth and development occurred best at temperatures at which ordinary protoplasm becomes inert or dies. The best growths were always obtained at 55-65° C. Their wide distribution was of a striking nature. They were found by us in river water and mud, in sewage and also in a sample of sea water. They were present in the digestive tract of man and animals, and in the surface and deep layers of the soil, as well as in straw and in all samples of ensilage examined. Their rapid growth at high temperatures was remarkable, the whole surface of the culture medium being frequently overrun in from fifteen to seventeen hours. The organisms examined by us (fourteen forms in all) belonged to the group of the Bacilli. Some were motile, some curdled milk and some liquefied gelatin in virtue of a proteolytic enzyme. The majority possessed reducing powers upon nitrates and decomposed proteid matter. In some instances cane sugar was inverted and starch was diastased. These facts well illustrate the full vitality of the organisms at these high temperatures, whilst all the organisms isolated grew best at 55-65° C. A good growth in a few cases occurred at 72° C. Evidence of growth was obtained even at 74° C. They exhibited a remarkable and unique range of temperature, extending as far as 30° of the Centigrade scale.

As a concluding instance of the activity of these organisms we may cite their action upon cellulose. Cellulose is a substance that is exceedingly difficult to decompose, and is, therefore, used in the laboratory for filtering purposes in the form of Swedish filter paper, on account of its resistance to the action of solvents. We allowed these organisms to act on cellulose at 60° C. The result was that in ten to fourteen days a complete disintegration of the cellulose had taken place, probably in CO_2 and marsh gas. The exact conditions that may favor their growth, even if it be slow at subthermophilic temperatures, are not yet known—they may possibly be of a chemical nature.

Organisms may be gradually *acclimatized* to temperatures that prove unsuited to them under ordinary conditions. Thus the anthrax bacillus, with an optimum temperature for its development of 37° C., may be made to grow at 12° C., and at 42° C. Such anthrax bacilli proved pathogenic for the frog with a temperature of 12° C., and for the pigeon with a temperature of 42° C.

Let us, in a very few words, consider the inimical action of temperature on bacterial life. An organism placed below its minimum temperature ceases to develop, and if grown above its optimum temperature becomes attenuated as regards its virulence, etc., and may eventually die. The boiling point is fatal for non-sporing organisms in a few minutes. The exact thermal death-point varies according to the optimum and maximum temperature for the growth of the organism in question. Thus, for water bacteria with a low optimum temperature, blood heat may be fatal; for pathogenic bacteria developing best at blood heat, a thermophilic temperature may be fatal (60° C.); and for thermophilic bacilli any temperature above 75° C. These remarks apply to the bacteria during their multiplying and vegetating phase of life. In their resting or spore stage the organisms are much more resistant to heat. Thus the anthrax organism in its bacillary phase is killed in one minute at 70° C.; in its spore stage it resists this temperature for hours, and is only killed after some minutes by boiling. In the soil there are spores of bacteria which require boiling for sixteen hours to ensure their death. These are important points to be remembered in sterilization or disinfection experiments, viz., whether an organism does or does not produce these resistant spores. Most non-sporing forms are killed at 60° C. in a few minutes, but in an air-dry condition a longer time is necessary. Dry heat requires a longer time to act than moist heat: it requires 140° C. for three hours to kill anthrax spores. Dry heat cannot, therefore, be used for ordinary disinfection on account of its destructive action. Moist heat in the form of steam is the most effectual disinfectant, killing anthrax spores at boiling point in a few minutes, whilst a still quicker action is obtained if saturated steam under pressure be used. No spore, however resistant, remains alive after one minute's exposure to steam at 140° C. The varying thermal death-point of organisms and the problems of sterilization cannot be better illustrated than in the case of milk, which is an admirable soil for the growth of a large number of bacteria. The most obvious example of this is the souring and curdling of milk that occurs after it has been standing for some time. This change is mainly due to the lactic acid bacteria, which ferment the milk sugar with the production of acidity.

Another class of bacteria may curdle the milk without souring

it in virtue of a rennet-like ferment, whilst a third class precipitate and dissolve the casein of the milk, along with the development of butyric acid. The process whereby milk is submitted to a heat of 65° to 70° C. for twenty minutes is known as pasteurization, and the milk so treated is familiar to us all as pasteurized milk. Whilst the pasteurizing process weeds out the lactic acid bacteria from the milk, a temperature of 100° C. for one hour is necessary to destroy the butyric acid organisms: and even when this has been accomplished there still remain in the milk the spores of organisms which are only killed after a temperature of 100° C. for three to six hours. It will, therefore, be seen that pasteurization produces a partial, not a complete sterilization of the milk as regards its usual bacterial inhabitants. The sterilization to be absolute would require six hours at boiling point. But for all ordinary practical purposes pasteurization is an adequate procedure. All practical hygienic requirements are likewise adequately met by pasteurization, if it is properly carried out, and the milk is subsequently cooled. Milk may carry the infection of diphtheria, cholera, typhoid and scarlet fevers, as well as the tubercle bacillus from a diseased animal to the human subject. For the purpose of rendering the milk innocuous, freezing and the addition of preservatives are inadequate methods of procedure. The one efficient and trustworthy agent we possess is heat. Heat and cold are the agents to be jointly employed in the process, viz., a temperature sufficiently high to be fatal to organisms producing a rapid decomposition of milk, as well as to those which produce disease in man; this is to be followed by a rapid cooling to preserve the fresh flavor and to prevent an increase of the bacteria that still remain alive. The pasteurized process fulfils these requirements.

In conjunction with Dr. Hewlett, I had occasion to investigate in how far the best pasteurizing results might be obtained. We found that 60° to 68° C. applied for twenty minutes weeded out about 90 per cent. of the organisms present in the milk, leaving a 10 per cent. residue of resistant forms. It was found advisable to fix the pasteurizing temperature at 68° C., in order to make certain of killing any pathogenic organisms that may happen to be present. We passed milk in a thin stream through a coil of metal piping, which was heated on its outer surface by water. By regulating the length of the coil, or the size of the tubing, or the rate of flow of the milk, almost any desired temperature could be obtained. The temperature we ultimately fixed at 70° C. The cooling was carried out in similar coils placed in iced water. The thin stream of milk was quickly heated and quickly cooled as it passed through the heated and cooled tubing, and whilst it retained its natural flavor, the apparatus ac-

complished at 70° C. in thirty seconds a complete pasteurization, instead of in twenty minutes, i. e., about 90 per cent. of the bacteria were killed, whilst the diphtheria, typhoid, tubercle and pus organisms were destroyed in the same remarkably short period of time, viz., thirty seconds. This will serve to illustrate how the physical agent of heat may be employed, as well as the sensitiveness of bacteria to heat when it is adequately employed.

Bacteria are much more sensitive to high than to low temperatures, and it is possible to proceed much further downwards than upwards in the scale of temperature, without impairing their vitality. Some will even multiply at zero, whilst others will remain alive when frozen under ordinary conditions.

I will conclude this discourse by briefly referring to experiments recently made with most remarkable results upon the influence of low temperatures on bacterial life. The experiments were conducted at the suggestion of Sir James Crichton-Browne and Professor Dewar. The necessary facilities were most kindly given at the Royal Institution, and the experiments were conducted under the personal supervision of Professor Dewar. The action of liquid air on bacteria was first tested. A typical series of bacteria was employed for this purpose, possessing varying degrees of resistance to external agents. The bacteria were first simultaneously exposed to the temperature of liquid air for twenty hours (about −190° C.). In no instance could any impairment of the vitality of the organisms be detected as regards their growth of functional activities. This was strikingly illustrated in the case of the phosphorescent organisms tested. The cells emit light which is apparently produced by a chemical process of intracellular oxidation, and the phenomenon ceases with the cessation of their activity. These organisms, therefore, furnished a very happy test of the influence of low temperatures on vital phenomena. These organisms when cooled down in liquid air became non-luminous, but on re-thawing the luminosity returned with unimpaired vigor as the cells renewed their activity. The sudden cessation and rapid renewal of the luminous properties of the cells, despite the extreme changes of temperature, was remarkable and striking. In further experiments the organisms were subjected to the temperature of liquid air for seven days. The results were again *nil*. On re-thawing the organisms renewed their life processes with unimpaired vigor. We had not yet succeeded in reaching the limits of vitality. Professor Dewar kindly afforded the opportunity of submitting the organisms to the temperature of liquid hydrogen—about −250° C. The same series of organisms was employed, and again the result was *nil*. This temperature is only 21° above that of the absolute zero, a temperature at which, on our present theoretical conceptions, molecular movement

ceases and the entire range of chemical and physical activities with which we are acquainted either cease, or, it may be, assume an entirely new rôle. This temperature again is far below that at which any chemical reaction is known to take place. The fact, then, that life can continue to exist under such conditions affords new ground for reflection as to whether after all life is dependent for its continuance on chemical reactions. We, as biologists, therefore follow with the keenest interest Professor Dewar's heroic attempts to reach the absolute zero of temperature; meanwhile, his success has already led us to reconsider many of the main issues of the problem. And by having afforded us a new realm in which to experiment, Professor Dewar has placed in our hands an agent of investigation from the effective use of which we who are working at the subject at least hope to gain a little further insight into the great mystery of life itself.

FLIES AND TYPHOID FEVER.

By Dr. L. O. HOWARD,
U. S. DEPARTMENT OF AGRICULTURE.

AFTER the outbreak of the late war with Spain in the early summer of 1898, typhoid fever soon became prevalent in concentration camps in different parts of the country. In many cases—in fact in fully one-half of the total number—the fever was not recognized as typhoid for some time, but towards the close of the summer it was practically decided that the fever which prevailed was not malarial, but enteric. During that summer the medical journals and the newspapers contained a number of communications from contract surgeons and others advancing the theory that flies were largely responsible for the spread of the disease, owing to the fact that in many of these camps the sinks or latrines were placed near the kitchens and dining tents, and that the enormous quantity of excrement in the sinks was not properly cared for. One of the most forcible writers on this topic was Dr. H. A. Veeder, whose paper, entitled 'Flies as Spreaders of Disease in Camps,' published in the 'New York Medical Record' of September 17, 1898, brought together a series of observations and strong arguments in favor of his conclusion that flies are prolific conveyors of typhoid under improper camp conditions.

This idea was not a new one. Following the proof of the agency of flies in the transmission of Asiatic cholera by Tizzoni and Cattani, Sawtchanko, Simmonds, Uffelmann, Flugge and Macrae, it was shown by Celli as early as 1888 that flies fed on the pure cultures of *Bacillus typhi abdominalis* are able to transmit virulent bacilli in their excrement. Dr. George M. Kober, of Washington, in his lectures before the Medical College of Georgetown University, had for some years been insisting upon the agency of flies in the transmission of typhoid, and in the report of the health officer of the District of Columbia for the year ending June 30, 1895, referred to the probable transferrence of typhoid germs from the privies and other receptacles for typhoid stools to the food supply of the house by the agency of flies.

Moreover, the Surgeon-General of the Army, Dr. George M. Sternberg, was fully alive to the great importance of the isolation and disinfection of excrement, as evidenced in his prize essay on 'Disinfection and Personal Prophylaxis in Infectious Diseases,' published by the American Public Health Association in 1885, and in the first circular issued from his office in the spring of 1898 (April) careful instruc-

tions were given regarding the preparation of sinks and their care, with a direct indication of the danger of transfer of typhoid fever by flies. These instructions were not followed, and the result was that over 21 per cent. of the troops in the national encampments in this country during the summer of 1898 had typhoid fever, and over 80 per cent. of the total number of deaths during that year were from this one cause.*

This condition of affairs was not confined to the United States. An epidemic occurred in the camp of the Eighth Cavalry at Puerto Principe, Cuba, in which two hundred and fifty cases of the fever occurred. The disease was imported by the regiment into its Cuban camp, and Dr. Walter Reed, U. S. A., upon investigation, reported to the Surgeon-General that the epidemic "was clearly not due to water infection, but was transferred from the infected stools of the patients to the food by means of flies, the conditions being especially favorable for this manner of dissemination. . . . "†

In all the published accounts, and in all literature of closely allied subjects, the expression used in connection with the insects has been

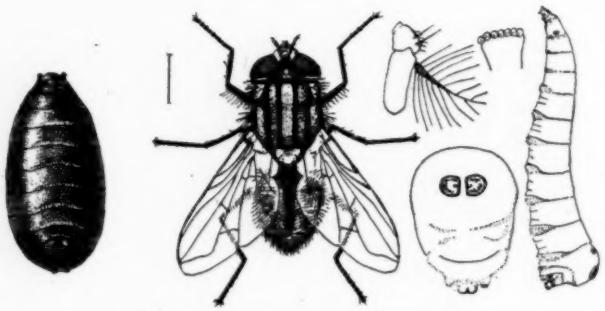

FIG. 1. MUSCA DOMESTICA—ENLARGED.

simply the word 'flies.' Nothing could be more unsatisfactory to the entomologist than such a general word as this, except it were taken for granted that the house-fly *(Musca domestica)* was always meant. It has not apparently been realized that there are many species of flies which are attracted to intestinal discharges, nor does it seem to have been realized that, while certain of these species may visit, and do visit, food supplies in dining rooms, kitchens and elsewhere, many others are not likely to be attracted.

In 1895, the writer made a study of the house-fly, not from this

* Conclusions reached after a study of typhoid fever among American soldiers in 1898, by Dr. Victor C. Vaughan, a member of the Army Typhoid Commission, read before the annual meeting of the American Medical Association at Atlantic City, N. J., June 6, 1900. 'Philadelphia Medical Journal,' June 9, 1900, pages 1315 to 1325.

† 'Sanitary Lessons of the War,' by George M. Sternberg, Surgeon-General, U. S. A., read at the meeting of the American Medical Association, at Columbus, O., June 6 to 9, 1899. 'Phila. Med. Jour.,' June 10 and 17, 1899.

standpoint, but from a desire to learn the principal source from which our houses are supplied with this eternal nuisance, with a view to being able to suggest remedial measures. Experimental work in this direction was continued for some years. In the course of this work he early decided that an overwhelming majority of the house-flies found in domiciles breed in horse manure. This substance is its favored larval food, and experimental work showed that by the semi-weekly treatment of the horse manure in one large stable, the house-fly supply of the neighborhood was very greatly reduced. In confined breeding cages he had been unable to breed house-flies in any other substance than horse-dung, and consequently when the camp typhoid question and the agency of flies became a matter of such general comment in 1898, he saw the desirability of a careful study of the insects which frequent or breed in human excrement, in order to give exact data from which reliable state-

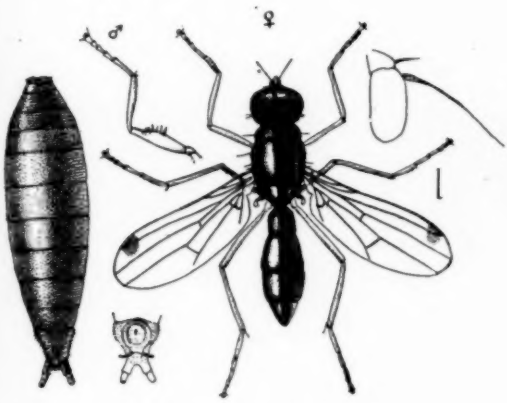

FIG. 2. SEPSIS VIOLACEA—ENLARGED.

FIG. 3. NEMOPODA MINUTA—ENLARGED.

ments could be made and upon which reliable conclusions could be based. This work was begun and carried on through the summer of 1899 and to some extent in the summer of 1900, with results which will be briefly summarized in the following paragraphs. The exact details, somewhat too technical, altogether too long and certainly too unpleasant for publication in a journal of this character, will be published in the Proceedings of the Washington Academy of Sciences.

In all seventy-seven distinct species of flies, belonging to twenty-one different families, were found by actual observation, either by rearing or by captures, to be coprophagous; thirty-six species were found to breed in human fæces under more or less normal conditions, while forty-one were captured upon such material. All have been studied with more or less care, and their other habits ascertained. The most

abundant of the flies reared were *Helicobia quadrisetosa, Sepsis violacea, Nemopoda minuta, Limosina albipennis, Limosina fontinalis, Sphærocera subsultans* and *Scatophaga furcata,* while the most abundant forms captured were *Phormia terrænovæ* and *Borborus equinus.* In a second class, not including the most abundant forms reared and captured, but including species which were rather abundantly found, were *Sarcophaga sarraceniæ, Sarcophaga assidua, Sarcophaga trivialis, Musca domestica* (the common house-fly), *Morellia micans, Muscina stabulans, Myospila meditabunda, Ophyra leucostoma, Phorbia cinerella,* and *Sphærocera pusilla,* of the reared series, and *Pseudopyrellia cornicina* and *Limosina crassimana* among the captured series. All the others of the seventy-seven species were either scarce or not abundant.

The results so far stated and the observations made in the investigation as a whole have a distinct entomological interest, as showing the exact food habits of a large number of species, many of the obser-

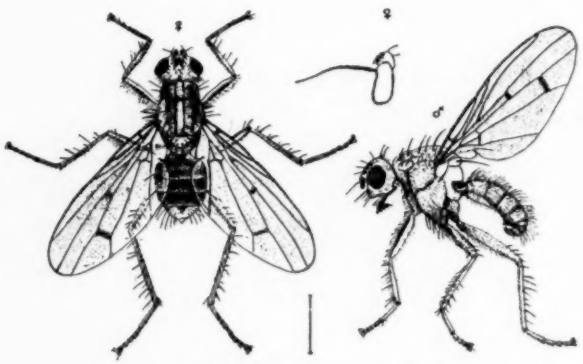

FIG. 4. SCATOPHAGA FURCATA—ENLARGED.

vations being novel contributions to the previous knowledge of these forms. But the principal bearings of the work are only brought out when we consider which of these forms are likely, from their habits, actually to convey disease germs from the substance in which they have bred or which they have frequented to substances upon which people feed. Therefore, collections of the Dipterous insects (flies) occurring in kitchens, pantries and dining rooms were made, with the assistance of correspondents and observers in different parts of the country, through the summer of 1899, and also in the summer and autumn of 1900. Such collections were made in the States of Massachusetts, New York, Pennsylvania, District of Columbia, Florida, Georgia, Louisiana, Nebraska and California. Nearly all of the flies thus captured were caught upon sheets of the ordinary sticky fly-paper, which, while ruining them as cabinet specimens, did not disfigure them beyond the point of specific recognition.

In all 23,087 flies were examined.* They were caught in rooms in which food supplies are ordinarily exposed, and may safely be said to have been attracted by the presence of these food supplies. Of these 23,087 flies, 22,808 were *Musca domestica;* that is to say, 98.8 per cent. of the whole number captured belonged to the species known as the common house-fly. The remainder, consisting of 1.2 per cent. of the whole, comprised various species, the most significant ones being *Homaloymia canicularis* (the species ordinarily known as the 'little house-fly'), of which 81 specimens were captured; the stable-fly *(Muscina stabulans),* 37 specimens; *Phora femorata,* 33; *Lucilia cæsar* (screw-worm fly), 8; *Drosophila amelophila,* 15; *Sarcophaga trivialis,* 10; and *Calliphora erythrocephala* (the common blow-fly), 7.

Musca domestica is, therefore, the species of greatest importance from

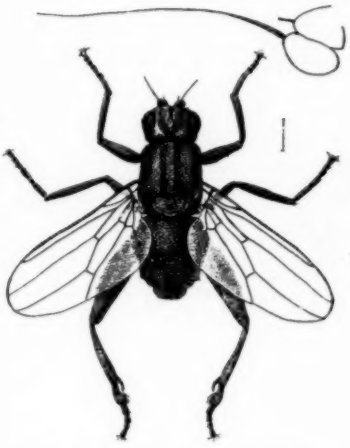

FIG. 5. SPHÆROCERA SUBSULTANS—ENLARGED.

FIG. 6. PHORMIA TERRÆNOVÆ—ENLARGED.

the food-infesting standpoint; *Homaloymia canicularis* is important and *Muscina stabulans* is of somewhat lesser importance. *Drosophila amelophila,* although not occurring in the former list of abundant species, does rarely breed in excreta and is an important form; it would have been much more abundant in the records of house captures had more of these been made in the autumn, after fruit makes its appearance upon the dining tables and sideboards, since this species is the commonest of the little fruit-flies which are seen flying about ripe fruit in the fall of the year. The Calliphora and the Lucilia are of slight importance, not only on account of their rarity in houses, but because they are not, strictly speaking, true excrement insects. They

* The determination work in the Diptera was all done by the writer's assistant, Mr. D. W. Coquillett, who is an authority on this group of insects.

are rather carrion species. Other forms were taken, but either their household occurrence was probably accidental or from their habits they have no significance in the disease-transfer function.

It appears plainly that the most abundant species breeding in or attracted to dejecta do not occur in kitchens and dining rooms, but it is none the less obvious that while the common house-fly, under ordinary city and town conditions as they exist at the present day, and more especially in such cities and towns, or in such portions of cities as are well cared for and inhabited by a cleanly and respectable population, may not be considered an imminent source of danger, it is, nevertheless, under other conditions a factor of the greatest importance in the spreading of enteric fever.

The house-fly undoubtedly prefers horse manure as a breeding place. We have shown that it is not one of the most abundant species of flies breeding in or attached to human fæces, but, in the course of the observations made in the summer of 1899, we have definitely proved

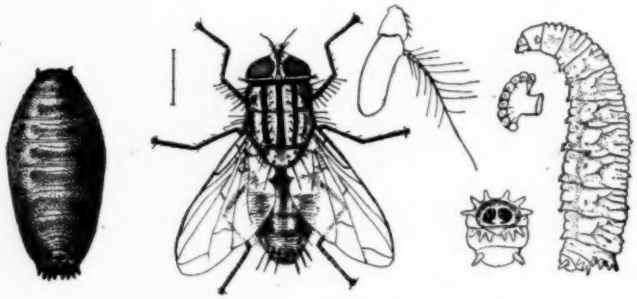

FIG. 7. SARCOPHAGA ASSIDUA—ENLARGED.

the following facts relative to the house-fly, and in the statement of these facts it must be remembered that every specimen has been carefully examined by an expert dipterologist, so that there can be no mistake:

(1.) In the army camps the latrines are not properly cared for and where their contents are left exposed, *Musca domestica* will, and does, breed in these contents in large numbers, and is attracted to them without necessary oviposition.

Such observations were not made by the writer at the concentration camps of 1898, but were made at the summer camps of the District of Columbia Militia, during the summers of 1899 and 1900.

The contrast between the conditions here observed and those which existed at the great army camp at the Presidio, San Francisco, California, as observed by the writer through the courtesy of Surgeon-General Sternberg and Colonel W. H. Forwood, surgeon in charge of the Department of California, in the late autumn of 1899, was most

striking. At the Presidio camp, the chance for the transfer of typhoid by flies had by intelligent care been reduced to zero. This, however, was, of course, a more or less permanent camp and opportunities were better, but indicated in a beautiful way what might be done and what should be done even in a temporary camp.

(2) In towns where the box privy nuisance is still in existence the house-fly is attracted to such places to a certain extent, though not as abundantly as other flies, which, however, are not found in houses. Observations to this effect were made by the writer and his assistants in many parts of the United States.

(3.) In the filthy regions of a city, where sanitary supervision is lax, and where in low alleys and corners and vacant lots deposits are made by dirty people, the house-fly is attracted to the stools, may breed in them, and is thus a constant source of danger. The writer has seen a deposit made over night in South Washington in an alleyway swarm-

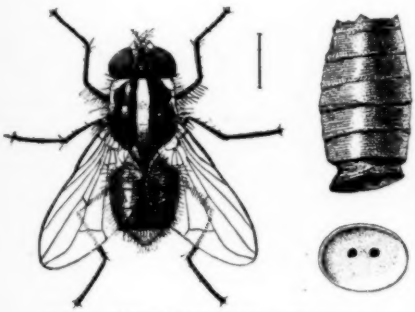

FIG. 8. MORELLIA MICANS—ENLARGED.

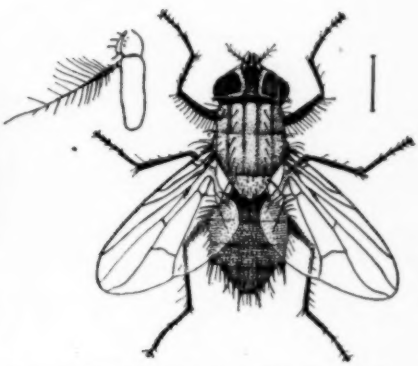

FIG. 9. MYOSPILA MEDITABUNDA—ENLARGED.

ing with flies, in the bright sunlight of a June morning, temperature 92° F., and within thirty feet of this substance were the open doors and windows of the kitchens of two houses occupied by poor people, these two houses being only elements in a long row.

The conclusions which the writer has reached after two years of this experimental work are:

(1) Of the seventy-seven species of flies found under such conditions that their bodies, especially their feet and their proboscides, may become covered with virulent typhoid germs, only eight are likely to carry them to objects from which they can enter the alimentary canal of man.

(2) Of these eight species, two, namely, *Lucilia cæsar* and *Calliphora erythrocephala*, can very rarely carry such germs, though they may carry the germs of putrefaction and cause blood-poisoning, in alighting upon abrasions of the skin or open wounds.

(3) Four of these specimens, namely, *Homaloymia canicularis, Muscina stabulans, Phora femorata* and *Sarcophaga trivialis,* possess some degree of importance, but their comparative scarcity in houses renders them by no means of prime importance.

(4) The common little fruit-fly, *Drosophila ampelophila,* is a dangerous species.

(5) The house-fly is a constant source of danger, and wherever the least carelessness in the disposal of or the disinfection of dejecta exists, it becomes an imminent source of danger.

When we consider the prevalence of typhoid fever and the fact that virulent typhoid bacilli may occur in the excrement of an individual for some time before the disease is recognized in him, and that virulent germs may be found in the excrement for a long time after the apparent recovery of a patient, the wonder is not that typhoid is so prevalent, but that it does not prevail to a much greater extent.

FIG. 10. MUSCINA STABULANS—ENLARGED.

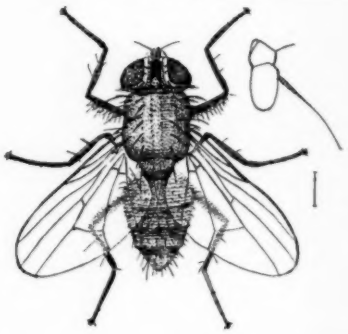

FIG. 11. PHORBIA CINERELLA—ENLARGED.

Box privies should be abolished in every community, or they should be disinfected daily. The depositing of excrement in the open within the town or city limits should be considered a punishable misdemeanor in cities which have not already such regulations, and the law should be enforced more vigorously in towns in which it is already prohibited. Such offenses are generally committed after dark, and it is often difficult, or even impossible, to trace the offender; therefore, the regulations should be carried even further, and should require the first responsible person who notices the deposit to immediately inform the police, so that it may be removed or covered up. Dead animals are so reported, but human excrement is much more dangerous. Boards of health in all communities should look after the proper treatment or disposal of horse manure, primarily in order to reduce the number of house-flies to a minimum, and all regulations regarding the disposal of garbage and foul matter should be made more stringent and should be more stringently enforced.

GEOMETRY: ANCIENT AND MODERN.

BY PROFESSOR EDWIN S. CRAWLEY,
UNIVERSITY OF PENNSYLVANIA.

AMONGST the records of the most remote antiquity we find little to lead to the conclusion that geometry was known or studied as a branch of mathematics. The Babylonians had a remarkably well-developed number system and were expert astronomers; but, so far as we know, their knowledge of geometry did not go beyond the construction of certain more or less regular figures for necromantic purposes. The Egyptians did better than this, and Egypt is commonly acknowledged to be the birthplace of geometry. It was a poor kind of geometry, however, from our point of view, and should rather be designated as a system of mensuration. Nevertheless it served as a beginning, and probably was the means of setting the Greek mind at work upon this subject. Our knowledge of Egyptian geometry is obtained from a papyrus in the British Museum known as the Ahmes Mathematical Papyrus. It dates from about the eighteenth century B. C., and purports to be a copy of a document some four or five centuries older. It is the counterpart of what to-day is called an engineer's hand-book. It contains arithmetical tables, examples in the solution of simple equations, and rules for determining the areas of figures and the capacity of certain solids. There is no hint of anything in the nature of demonstrational geometry, nor any evidence of how the rules were derived. In fact, they could not have been obtained as the result of demonstration, for they are generally wrong. For example, the area of an isosceles triangle is given as the product of the base and half the side, and that of a trapezoid as the product of the half-sums of the opposite sides. These rules give results which are approximately correct so long as they are applied to triangles whose altitude is large compared with the base, and to trapezoids which do not depart very far from a rectangular shape. Whether the Egyptians ever came to realize that these rules were erroneous we cannot say, but it is known that long after the Greeks had discovered the correct ones they were still in use. Thus Cajori, 'History of Mathematics,' page 12, says: "On the walls of the celebrated temple of Horus at Edfu have been found hieroglyphics written about 100 B. C., which enumerate the pieces of land owned by the priesthood and give their areas. The area of any quadrilateral, however irregular, is there found by the formula $\frac{a+b}{2} \times \frac{c+d}{2}$." [$a$ and b stand for one pair of opposite sides and c and d for the others.] It is plausibly argued that a superstitious tra-

ditionalism made it an act of sacrilege to alter what had become part of the sacred writings.

When we consider the conditions of life in Egypt we can easily see why this particular kind of geometric knowledge so early gained currency. The annual inundation of the Nile was continually altering the minor features of the country along its course, and washing away landmarks between adjacent properties. Some means of re-establishing these marks and of determining the areas of fields was therefore essential. To meet this demand the surveyors devised the rules which Ahmes has given us. The further necessity of ascertaining the contents of a barn of given shape and dimensions likewise gave rise to the rules for determining volumes.

We learn also that the Egyptians were acquainted with the truth of the Pythagorean theorem, that the square of the hypotenuse of a right triangle is equal to the sum of the squares of the other two sides, for they applied this knowledge practically by means of a triangle whose sides were 3, 4 and 5 respectively, in laying down right angles. This general truth was derived in all probability by deduction from a large number of individual cases. The Egyptian rule for the area of a circle was remarkably accurate for such an early date. It consisted in squaring eight-ninths of the diameter. This gives to π the value 3.1605.

It is generally supposed that the Greeks had their attention drawn to geometry through intercourse with the Egyptians. It was but a step, however, for them to pass beyond the latter, and with them we find the birth of the true mathematical spirit which refuses to accept anything upon authority, but requires a logical demonstration. It is well known what an important place was held by geometry in Greek philosophy. The Pythagorean school contributed much that was important along with a great deal that was fanciful and of little value. Pythagoras himself was the first to prove the theorem referred to above, which goes by his name. The Greeks for the most part pursued the study of geometry as a purely intellectual exercise. Anything in the nature of practical applications of the subject was repugnant to them, and hence but little attention was paid to theorems of mensuration. This reminds one of the story told of a professor of mathematics in modern times who, in beginning a course of lectures, made the remark: "Gentlemen, to my mind the most interesting thing about this subject is that I do not see how under any circumstances it can ever be put to any practical use." Euclid in his 'Elements' does not mention the theorem that the area of a triangle is equal to half the product of its base and altitude, nor does he enter into any discussion of the ratio of the circumference to the diameter of a circle. This last, however, was a problem which as early as the time of Pythagoras had attracted much attention. 'Squaring the circle' was a stumbling block to the Greeks and has been ever since.

The pursuit of the impossible seems to have an irresistible attraction for some minds. This remark applies only to the modern devotees of the subject, however. The Greeks did not know that the thing they sought was an impossibility. To square the circle, to trisect an angle and to duplicate the cube were three problems upon which the Greeks lavished more attention probably than upon any others. It was not labor wasted, because it led incidentally to many theorems, which otherwise might have remained unknown, but the principal object sought was not attained. To make matters clear it should be stated that to meet the requirements of Greek geometry the instruments used in the solution must be only the compasses and the unmarked straight edge. So that to square the circle meant to construct by these means the side of a square whose area should equal that of a given circle. The Greeks eventually succeeded in solving the last two problems by the aid of curves other than the circle, but this, of course, was unsatisfactory. As we know now they were pursuing *ignes fatui*. Nevertheless it is brought to the knowledge of mathematicians with painful frequency that a vast amount of energy is still wasted upon these problems, especially the first. Let me, therefore, take the space here to repeat that squaring the circle is not simply one of the unsolved problems of mathematics which is awaiting the happy inspiration of some genius, but that it has been ably demonstrated to be incapable of solution in the manner proposed.

When Euclid compiled his 'Elements' the knowledge of geometry current amongst the Greeks was about the same as that which we have to-day under the name of elementary geometry. The term Euclidean geometry has a somewhat different signification, which will be explained below.

About a century before Euclid's time the Greeks discovered the conic sections, and Apollonius of Perga, who lived about a century after Euclid, brought the geometry of these curves to a high degree of perfection. Archimedes, whose time was intermediate between that of Euclid and of Apollonius, had a more practical turn of mind and applied his mathematical knowledge to useful purposes. Amongst other things he showed that the value of π lies between $3\frac{1}{7}$ and $3\frac{10}{71}$ that is, between 3.1429 and 3.1408, a closer approximation than the Egyptian.

We see, therefore, that in the few centuries during which the Greeks occupied themselves with the study of geometry the knowledge of the right line, circle and conic sections reached about as high a state of development as it was possible to attain until the invention of more powerful methods of research, and many centuries were destined to elapse before this was to occur. I do not overlook the fact that the beautiful and extensive modern geometry of the triangle and the systems of re-

markable points and circles associated with it, which has been developed by Brocard, Lemoine, Emmerich, Vigarié and others, was within the reach of the Greeks; but this does not destroy the force of the remark above.

The operations of mathematics are divided fundamentally into two kinds, analytic, which employ the symbolism and methods of algebra (in its broadest sense), and geometric, which consists of the operation of pure reason upon geometric figure. The two are now only partially exclusive, however, for analysis is frequently assisted by geometry, and geometric results are frequently obtained by analytic methods.

With the Greeks, Hindoos and Arabs, the only peoples who concerned themselves to any extent with mathematics until comparatively modern times, the operations of algebra and geometry were entirely distinct. With the Hindoos and Arabs algebra received more attention than geometry and with the Greeks the reverse was true. Many of the theorems of Euclid are capable of an algebraic interpretation, and this fact was probably well known, but nevertheless the theorems themselves are expressed in geometric terms and are proved by purely geometric means; and they do not, therefore, constitute a union of analysis with geometry in the modern sense.

The seventeenth century brought the invention of analytic geometry by Descartes and that of the calculus by Newton and Leibnitz. These methods opened hitherto undreamed-of possibilities in geometric research and led to the systematic study of curves of all descriptions and to a generalization of view in connection with the geometry of the right line, circle and conics, as well as of the higher curves, which has been of the greatest value to the modern mathematician. To point out by a very simple illustration the nature of this work of generalization let us consider the case of a circle and straight line in the same plane, the line being supposed to be of indefinite extent. According to the relative position of this line and circle the Greek geometer would say that the line either meets the circle, or is tangent to the circle, or that the line does not meet the circle at all. We say now, however, that the line always meets the circle in two points, which may be real and distinct, real and coincident or imaginary. Thus a condition of things which the Greek was obliged to consider under three different cases we can deal with now as a single case. This generalized view is a direct consequence of the analytic treatment of the question.

It will be seen from the illustration used above that two very important conceptions are introduced into geometry by the use of the analytic method. One of these is the conception of coincident or consecutive points of intersection, as in the case of a tangent, and the other is that of imaginary elements, as in the case of the imaginary points of

intersection of a line and circle which are co-planar and non-intersecting in the ordinary sense. It is impossible to exaggerate the importance of these conceptions. Without them the beautiful fabric of modern geometry would not stand a moment. It will be seen to many readers, no doubt, that a fabric built upon such a foundation will have very much the same stability as a 'castle in Spain.' Such, however, is far from the case. The analysis by which our operations proceed is a thoroughly well founded and trustworthy instrument, and when we give to it the geometric interpretation which we are entirely justified in doing, we find frequently that it reveals to us facts which our senses unaided by its finer powers of interpretation could not have discovered. These facts require for their adequate explanation the recognition of the so-called imaginary elements of the figure. Let us take one more illustration. If from a point outside of, but in the same plane with, a circle we draw two tangents to the circle and connect the points of tangency with a straight line, the original point and the line last mentioned stand in an important relation to each other and are called respectively pole and polar with regard to the circle. Now suppose the point is inside the circle. The whole construction just described becomes then geometrically impossible, but analytically we can draw from a point within a circle two imaginary tangents to the circle, and similarly we can connect the imaginary points of tangency by a straight line, and this straight line is found to be a real line. Moreover, in its relations to the point and circle it exhibits precisely the same properties which are found in the case of the pole and polar first described. Hence this point and line are also included in the general definition of pole and polar. Such examples might be multiplied indefinitely, but they would all go to emphasize the fact of the great power of generalization which resides in the methods of analytic geometry.

While the power of the analytic method as an instrument of research is far greater than that of the older pure geometric method, yet to many minds it lacks somewhat the beauty and elegance of that method as an intellectual exercise. This is due to the fact that its operations, like all algebraic operations, are largely mechanical. Given the equations representing a certain geometric condition, we subject these equations to definite transformations and the results obtained denote certain new geometric conditions. We have been whisked from the data to the result very much as we are hurried over the country in a railroad train. We may have noted the features of the country as we passed through it or we may not; we arrive at our destination just the same. Pure geometric research, on the other hand, resembles travel on foot or horseback. We must scrutinize the landmarks and keep a careful watch on the direction in which we are traveling, lest we take a wrong turn and fail to reach our destination. The result is that we

acquire a thorough familiarity with the country through which we pass. The analytical method, however, affords abundant opportunity for mental activity, although of a different kind from that required in the other. First, the most advantageous analytic expression for the given geometric conditions must be sought; then the proper line of analytic transformation must be determined upon; and finally the result must be interpreted geometrically. This last step requires keen insight in order to ensure the full value of the result, for it is here that we often find far more than we anticipated, or than a casual glance will reveal.

The obligation thus incurred by geometry to analysis has been largely repaid by the aid which analysis has derived from geometry. The study of pure analysis is unquestionably the most abstruse branch of mathematics, but it is now advancing with rapid strides and demands less and less the aid of geometry. The results of the analytic method in geometry, however, are too fruitful for it to be either desirable or possible for us to go back to a condition of complete separation of these two methods.

Amongst the distinctly modern developments of geometry is what is known as hyper-geometry, the geometry of space of more than three dimensions. The fact that the product of two linear dimensions is representable by an area, and the product of three linear dimensions by a volume, naturally leads us to ask what is the geometric representative of the product of four or more linear dimensions. The answer to this question leads to the ideal conception of space of four or more dimensions. Just as in space of three dimensions, the space of our every-day experience, we can draw three concurrent straight lines such that each one is perpendicular to each of the other two, so in space of four dimensions it must be possible to draw four concurrent straight lines such that each one is perpendicular to each of the other three. It is needless to say it transcends the power of the human mind to form such a conception, nevertheless it is possible to study the geometry of such a space, and much has been done in this way both analytically and by the methods of pure geometry. If our space has a fourth dimension (not to speak of any higher dimension) as some mathematicians seem disposed seriously to maintain, a body moved from any position in the direction of the fourth dimension will disappear from view. In fact, it will be annihilated so far as we are concerned. Again, a body placed in an inclosed space can be removed therefrom while the walls of the envelope remain intact; or the envelope itself can be turned inside out without rupturing the walls. For example, it would be possible to extract the meat from an egg and leave the shell unbroken. For most persons, however, the geometry of four-dimensional space is likely to remain a mathematical curiosity, serving no useful purpose except to furnish an opportunity for acute logical reasoning, for in

studying the geometry of such space we have only our reasoning powers to guide us and cannot fall back upon experience, as we so often do more or less unconsciously, perhaps, in ordinary geometry.

Geometry of three-dimensional space is often studied by projecting the solid in question upon two or more planes and working with these plane projections instead of with the solid itself. This is done exclusively in descriptive geometry, the geometry of the engineer and builder with their plan and elevation, so called. The geometry of four-dimensional figures has been studied in an analogous way. A four-dimensional figure, it should be remarked, is a figure whose bounding parts are three dimensional figures, just as a three-dimensional figure is one whose bounding parts are surfaces or two-dimensional figures. A four-dimensional figure can be projected on a three-dimensional space and its properties studied from such projections made from different points of view, corresponding to the plan and elevation of ordinary geometry. The mathematical department of the University of Pennsylvania has in its possession wire models of solid projections of all the possible regular four-dimensional hyper-solids, the number of which is limited in the same way as is the number of regular three-dimensional solids. These models were constructed, after a careful study of the question, by Dr. Paul R. Heyl, a recent student and graduate of the University.

Amongst the subjects of most profound interest to mathematicians of recent years has been an investigation into the foundations of geometry and analysis. It was found, as the growth of the science proceeded, that much of fundamental importance, which hitherto had been accepted without question, would not bear searching scrutiny, and it began to be feared that the foundation might collapse in places altogether. We are concerned here with this only so far as it relates to geometry. Whatever may be said of geometry as a science which proceeds by pure reason from certain axioms, postulates and definitions, it is undoubtedly true that for at least the most fundamental conceptions we are thrown back upon experience; and that in the matter of axioms or postulates there is some latitude as to what we shall accept. Amongst the axioms or postulates given by Euclid is one known as the parallel-postulate, which states that if two coplanar straight lines are intersected by a third straight line (transversal) and if the interior angles on one side of the transversal are together less than two right angles, the two straight lines, if produced far enough, will meet on the same side of the transversal on which the sum of the interior angles is less than two right angles. This is, in fact, a theorem, and it is hardly possible to suppose that Euclid did not adopt it as a postulate only after finding that he could neither prove it nor do without it. It belongs to a set of theorems which are so connected that if the truth of

any one of them be assumed the others are readily proved. The theorem that the sum of the three angles of a triangle is equal to two right angles belong to this set. Ptolemy (Claudius Ptolemæus, second century A. D.) seems to have been the first to publish an attempted proof of this postulate of Euclid. Almost all mathematicians down to the beginning of the nineteenth century have given more or less attention to this question, and the account of their efforts to prove the postulate forms one of the most interesting chapters in the history of mathematics. Cajori, in his 'History of Elementary Mathematics,' says, page 270: "They all fail, either because an equivalent assumption is implicitly or explicitly made, or because the reasoning is otherwise fallacious. On this slippery ground good and bad mathematicians alike have fallen. We are told that the great Lagrange, noticing that the formulas of spherical trigonometry are not dependent upon the parallel-postulate, hoped to frame a proof on this fact. Toward the close of his life he wrote a paper on parallel lines and began to read it before the Academy, but suddenly stopped and said: 'Il faut que j'y songe encore' (I must think it over again); he put the paper in his pocket and never afterwards publicly recurred to it."

About the time to which I have referred, the end of the eighteenth and beginning of the nineteenth century, the idea began to force itself upon mathematicians that perhaps there was more in the question than appeared on the surface. It was one of the many instances which have occurred in all branches of human knowledge where some truth of fundamental importance has begun to force itself simultaneously on a number of minds. We leave the significance of this aspect of the question to the psychologists. Another curious fact to be noted in connection with the writings which have finally shown us the true meaning of the parallel-postulate is that either they attracted little or no general attention when they first appeared, or else they remained unpublished. The names of Lobatchewsky and the Bolyais have been made immortal by their writings on this subject, but it was not until long after they were published that their vast importance was recognized. The inimitable Gauss wrote on the same subject, but left his work unpublished, and Cajori (ibid., p. 274) mentions two writers of much earlier date who anticipated in part the theories of Lobatchewsky and the Bolyais. These are Geronimo Saccheri (1667-1733), a Jesuit father of Milan, and Johann Heinrich Lambert (1728-1777), of Mühlhausen, Alsace.

Lobatchewsky (Nicholaus Ivanovitch Lobatchewsky, 1793-1856) conceived the brilliant idea of cutting loose from the parallel-postulate altogether and succeeded in building up a system of geometry without its aid. The result is startling to one who has been taught to look upon the facts of geometry (that is, of the Euclidean geometry) as incon-

trovertible. The denial of the parallel-postulate leaves Lobatchewsky to face the fact that under the conditions given in the postulate the two lines, if continually produced, may never meet on that side of the transversal on which the sum of the interior angles is less than two right angles. In other words, through a given point we may draw in a plane any number of distinct lines which will never meet a given line in the same plane. A result of this is that the sum of the angles of a triangle is variable (depending on the size of the triangle), but is always less than two right angles. Notwithstanding the shock to our preconceived notions which such a statement gives, the geometry of Lobatchewsky is thoroughly logical and consistent. What, then, does it mean? Simply this: We must seek the true explanation of the parallel-postulate in the characteristics of the space with which we are dealing. The Euclidean geometry remains just as true as it ever was, but it is seen to be limited to a particular kind of space, space of zero-curvature the mathematicians call it; that is, for two dimensions, space which conforms to our common notion of a plane. Lobatchewsky's geometry, on the other hand, is the geometry of a surface of uniform negative curvature, while ordinary spherical geometry is geometry of a surface of uniform positive curvature. The Lobatchewskian geometry is sometimes spoken of as geometry on the pseudo-sphere.

The 'absolute geometry' of the Bolyais (Wolfgang Bolyai de Bolya, 1775-1856, and his son, Johann Bolyai, 1802-1860) is similar to that of Lobatchewsky. 'The Science Absolute of Space,' by the younger Bolyai, published as an appendix to the first volume of his father's work, has immortalized his name.

The work of Lobatchewsky and the Bolyais has been rendered accessible to English readers by the translations and contributions of Prof. George Bruce Halsted, of the University of Texas.

If we proceed beyond the domain of two-dimensional geometry we merge the ideas of non-Euclidean and hyper-space. The ordinary triply-extended space of our experience is purely Euclidean; and if we approach the conception of curvature in such a space it must be curvature in a fourth dimension, and here the mind refuses to follow, although by pure reasoning we can show what must take place in such a space.

H. Grassman, Riemann and Beltrami have written profoundly on these questions, and it is to the last that is due the discovery that the theorems of the non-Euclidean or Lobatchewskian geometry find their realization in a space of constant negative curvature.

We naturally ask the question: Is there any reason to suppose that the space which we inhabit is other than Euclidean? To this a negative reply must be returned. We may have suspicions, but we have no evidence. If we could discover a triangle the sum of whose angles by

actual measurement departs from two right angles, the fact of the non-Euclidean character of our space would be established at once. But no such triangle has been discovered. Even the largest, which are concerned in the measurement of stellar parallax, do not help us, and it does not seem possible to get larger ones. Nevertheless Clifford and others have shown that some physical phenomena, which require the conception of elaborate and complex machinery for their explanation, are capable of very simple explanation upon the hypothesis of a fourth dimension. Then, too, in the domain of pure mathematics several phenomena find a ready explanation upon the basis of such an assumption. In the theory of curves we constantly make use of the assumption that a curve may return into itself after passing through infinity, which is only another aspect of the same hypothesis. In fact, without this aid our processes of generalization, so important to the development of modern geometry, would be sadly hampered. Professor Newcomb has carried this matter to its logical conclusion and has deduced the actual dimensions of the visible universe in terms of the measurement of curvature in the fourth dimension. In such a space it becomes actually possible for a curve with infinite branches to pass through infinity (so-called) and return into itself. Upon this hypothesis our universe is unbounded in the sense that however far we travel we can never reach its limits, for it has none, but it is not infinite. Just as we can travel forever on the surface of the earth without reaching any limits, but that surface is not infinite. But even supposing that all this is true, the question still presses home: What is beyond?

AN ADDRESS GIVEN BEFORE THE DEPARTMENT OF ANTHROPOLOGY OF THE BRITISH ASSOCIATION, 1878.

By T. H. HUXLEY.

[Huxley's address at the Dublin meeting of the British Association gives an admirable account of the condition of anthropological science twenty-two years ago. It has not been republished in the 'Collected Essays,' but like everything that Huxley wrote it is worth reading at the present time.]

WHEN I undertook, with the greatest possible pleasure, to act as a lieutenant of my friend, the president of this section, I steadfastly purposed to confine myself to the modest and useful duties of that position. For reasons, with which it is not worth while to trouble you, I did not propose to follow the custom which has grown up in the Association of delivering an address upon the occasion of taking the chair of a section or department. In clear memory of the admirable addresses which you have had the privilege of hearing from Professor Flower, and just now from Dr. McDonnell, I can not doubt that that practice is a very good one; though I would venture to say, to use a term of philosophy, that it looks very much better from an objective than from a subjective point of view. But I found that my resolution, like a great many good resolutions that I have made in the course of my life, came to very little, and that it was thought desirable that I should address you in some way. But I must beg of you to understand that this is no formal address. I have simply announced it as a few introductory remarks, and I must ask you to forgive whatever of crudity and imperfection there may be in the mode of expression of what I have to say, although naturally I shall do my best to take care that there is neither crudity nor inaccuracy in the substance of it. It has occurred to me that I might address myself to a point in connection with the business of this department which forces itself more or less upon the attention of everybody, and which, unless the bellicose instincts of human nature are less marked on this side of St. George's Channel than on the other, may possibly have something to do with the large audiences we are always accustomed to see in the anthropological department. In the geological section I have no doubt it will be pointed out to you, or, at any rate, such knowledge may crop up incidentally, that there are on the earth's surface what are called *loci* of disturbance, where, for long ages, cataclysms and outbursts of lava and the like take place. Then everything subsides into quietude;

but a similar disturbance is set up elsewhere. In Antrim, at the middle of the tertiary epoch, there was a great center of physical disturbance. We all know that at the present time the earth's crust, at any rate, is quiet in Antrim, while the great centers of local disturbance are in Sicily, in Southern Italy, in the Andes and elsewhere. My experience of the British Association does not extend quite over a geological epoch, but it does go back rather longer than I care to think about; and when I first knew the British Association, the *locus* of disturbance in it was the geological section. All sorts of terrible things about the antiquity of the earth, and I know not what else, were being said there, which gave rise to terrible apprehensions. The whole world, it was thought, was coming to an end, just as I have no doubt that, if there were any human inhabitants of Antrim in the middle of the tertiary epoch, when those great lava streams burst out, they would not have had the smallest question that the whole universe was going to pieces. Well, the universe has not gone to pieces. Antrim is, geologically speaking, a very quiet place now, as well cultivated a place as one need see, and yielding abundance of excellent produce; and so, if we turn to the geological section, nothing can be milder than the proceedings of that admirable body. All the difficulties that they seemed to have encountered at first have died away, and statements that were the horrible paradoxes of that generation are now the commonplaces of school boys. At present the *locus* of disturbance is to be found in the biological section, and more particularly in the anthropological department of that section. History repeats itself, and precisely the same apprehensions which were expressed by the aborigines of the geological section, in long far back time, are at present expressed by those who attend our deliberations. The world is coming to an end, the basis of morality is being shaken, and I don't know what is not to happen if certain conclusions which appear probable are to be verified. Well, now, whoever may be here thirty years hence—I certainly shall not be—but, depend upon it, whoever may be speaking at the meeting of this department of the British Association thirty years hence will find, exactly as the members of the geological section have found, on looking back thirty years, that the very paradoxes and horrible conclusions, things that are now thought to be going to shake the foundations of the world, will by that time have become parts of every-day knowledge and will be taught in our schools as accepted truth, and nobody will be one whit the worse.

The considerations which I think it desirable to put before you, in order to show the foundations of this conviction at which I have very confidently arrived, are of two kinds. The first is a reason based entirely upon philosophical considerations, namely, this—that the region of pure physical science, and the region of those questions which

specially interest ordinary humanity, are apart, and that the conclusions reached in the one have no direct effect in the other. If you acquaint yourself with the history of philosophy, and with the endless variations of human opinion therein recorded, you will find that there is not a single one of those speculative difficulties which at the present time torment many minds as being the direct product of scientific thought, which is not as old as the times of Greek philosophy, and which did not then exist as strongly and as clearly as such difficulties exist now, though they arose out of arguments based upon merely philosophical ideas. Whoever admits these two things—as everybody who looks about him must do—whoever takes into account the existence of evil in this world and the law of causation—has before him all the difficulties that can be raised by any form of scientific speculation. And these two difficulties have been occupying the minds of men ever since man began to think. The other consideration I have to put before you is that, whatever may be the results at which physical science, as applied to man shall arrive, those results are inevitable—I mean that they arise out of the necessary progress of scientific thought as applied to man. You all, I hope, had the opportunity of hearing the excellent address which was given by our president yesterday, in which he traced out the marvellous progress of our knowledge of the higher animals which has been effected since the time of Linnæus. It is no exaggeration to say that at this present time the merest tyro knows a thousand times as much on the subject as is contained in the work of Linnæus, which was then the standard authority. Now how has that been brought about? If you consider what zoology, or the study of animals, signifies, you will see that it means an endeavor to ascertain all that can be studied, all the answers that can be given respecting any animal under four possible points of view. The first of these embraces considerations of structure. An animal has a certain structure and a certain mode of development, which means that it passes through a series of stages to that structure. In the second place, every animal exhibits a great number of active powers, the knowledge of which constitutes its physiology; and under those active powers we have, as physiologists, not only to include such matters as have been referred to by Dr. McDonnell in his observations, but to take into account other kinds of activity. I see it announced that the zoological section of to-day is to have a highly interesting paper by Sir John Lubbock on the habits of ants. Ants have a policy, and exhibit a certain amount of intelligence, and all these matters are proper subjects for the study of the zoologist as far as he deals with the ant. There is yet a third point of view in which you may regard every animal. It has a distribution. Not only is it to be found somewhere on the earth's surface, but paleontology tells us, if we go back in time, that

the great majority of animals have had a past history—that they occurred in epochs of the world's history far removed from the present. And when we have acquired all that knowledge which we may enumerate under the heads of anatomy, physiology and distribution, there remains still the problem of problems to the zoologist, which is the study of the causes of those phenomena, in order that we may know how they came about. All these different forms of knowledge and inquiry are legitimate subjects for science, there being no subject which is an illegitimate subject for scientific inquiry, except such as involves a contradiction in terms, or is itself absurd. Indeed, I don't know that I ought to go quite so far as this at present, for undoubtedly there are many benighted persons who have been in the habit of calling by no less hard names conceptions which the president of this meeting tells us must be regarded with much respect. If we have four dimensions of space we may have forty dimensions, and that would be a long way beyond that which is conceivable by ordinary powers of imagination. I should, therefore, not like to draw too closely the limits as to what may be contradiction to the best-established principles. Now, let us turn to a proposition which no one can possibly deny—namely, that there is a distinct sense in which man is an animal. There is not the smallest doubt of that proposition. If anybody entertains a misgiving on that point he has simply to walk through the museum close by, in order to see that man has a structure and a framework which may be compared, point for point and bone for bone, with those of the lower animals. There is not the smallest doubt, moreover, that, as to the manner of his becoming, man is developed, step by step, in exactly the same way as they are. There is not the smallest doubt that his activities—not only his mere bodily functions, but his other functions—are just as much the subjects of scientific study as are those of ants and bees. What we call the phenomena of intelligence, for example (as to what else there may be in them, the anthropologist makes no assertion)—are phenomena following a definite causal order just as capable of scientific examination, and of being reduced to definite law, as are all those phenomena which we call physical. Just as ants form a polity and a social state, and just as these are the proper and legitimate study of the zoologist, so far as he deals with ants, so do men organize themselves into a social state. And though the province of politics is of course outside that of anthropology, yet the consideration of a man, so far as his instincts lead him to construct a social economy, is a legitimate and proper part of anthropology, precisely in the same way as the study of the social state of ants is a legitimate object of zoology. So with regard to other and more subtle phenomena. It has often been disputed whether in animals there is any trace of the religious sentiment. That is a legitimate subject of dispute and of

inquiry; and if it were possible for my friend, Sir John Lubbock, to point out to you that ants manifest such sentiments, he would have made a very great and interesting discovery, and no one could doubt that the ascertainment of such a fact was completely within the province of zoology. Anthropology has nothing to do with the truth or falsehood of religion—it holds itself absolutely and entirely aloof from such questions—but the natural history of religion, and the origin and the growth of the religions entertained by the different kinds of the human race, are within its proper and legitimate province. I now go a step farther, and pass to the distribution of man. Here, of course, the anthropologist is in his special region. He endeavors to ascertain how various modifications of the human stock are arranged upon the earth's surface. He looks back to the past, and inquires how far the remains of man can be traced. It is just as legitimate to ascertain how far the human race goes back in time as it is to ascertain how far the horse goes back in time; the kind of evidence that is good in the one case is good in the other; and the conclusions that are forced on us in the one case are forced on us in the other also. Finally, we come to the question of the causes of all these phenomena, which, if permissible in the case of other animals, is permissible in the animal man. Whatever evidence, whatever chain of reasoning justifies us in concluding that the horse, for example, has come into existence in a certain fashion in time, the same evidence and the same canons of logic justify us to precisely the same extent in drawing the same kind of conclusions with regard to man. And it is the business of the anthropologist to be as severe in his criticism of those matters in respect to the origin of man as it is the business of the paleontologist to be strict in regard to the origin of the horse; but for the scientific man there is neither more nor less reason for dealing critically with the one case than with the other. Whatever evidence is satisfactory in one case is satisfactory in the other; and if any one should travel outside the lines of scientific evidence and endeavor either to support or oppose conclusions which are based upon distinctly scientific grounds, by considerations which are not in any way based upon scientific logic or scientific truth—whether that mode of advocacy was in favor of a given position, or whether it was against it, I, occupying the chair of the section, should, most undoubtedly, feel myself called upon to call him to order, and tell him that he was introducing topics with which we had no concern whatever.

I have occupied your attention for a considerable time, yet there is still one other point respecting which I should like to say a few words, because some very striking reflections arise out of it. The British Association met in Dublin twenty-one years ago, and I have taken the pains to look up what was done in regard to our subject at that period.

At that time there was no anthropological department. That study had not yet differentiated itself from zoology, or anatomy, or physiology so as to claim for itself a distinct place. Moreover, without reverting needlessly to the remarks which I placed before you some time ago, it was a very volcanic subject, and people rather liked to leave it alone. It was not until a long time subsequently that the present organization of this section of the Association was brought about; but it is a curious fact that although truly anthropological subjects were at the time brought before the geographical section—with the proper subject of which they had nothing whatever to do—I find, that even then, more than half of the papers that were brought before that section were, more or less distinctly, of an anthropological cast. It is very curious to observe what that cast was. We had systems of language—we had descriptions of savage races—we had the great question, as it then was thought, of the unity or multiplicity of the human species. These were just touched upon, but there was not an allusion in the whole of the proceedings of the Association, at that time, to those questions which are now to be regarded as the burning questions of anthropology. The whole tendency in the present direction was given by the publication of a single book, and that not a very large one—namely, 'The Origin of Species.' It was only subsequent to the publication of the ideas contained in that book that one of the most powerful instruments for the advance of anthropological knowledge—namely, the Anthropological Society of Paris—was founded. Afterwards the Anthropological Institute of this country and the great Anthropological Society of Berlin came into existence, until it may be said that, at the present time, there is not a branch of science which is represented by a larger or more active body of workers than the science of anthropology. But the whole of these workers are engaged, more or less intentionally, in providing the data for attacking the ultimate great problem, whether the ideas which Darwin has put forward in regard to the animal world are capable of being applied in the same sense and to the same extent to man.

That question, I need not say, is not answered. It is a vast and difficult question, and one for which a complete answer may possibly be looked for in the next century; but the method of inquiry is understood, and the mode in which the materials bearing on that inquiry are now being accumulated, the processes by which results are now obtained, and the observation of new phenomena lead to the belief that the problem also, some day or other, will be solved. In what sense I can not tell you. I have my own notion about it, but the question for the future is the attainment, by scientific processes and methods, of the solution of that question. If you ask me what has been done within the last twenty-one years towards this object, or rather towards clear-

ing the ground in the direction of obtaining a solution, I don't know that I could lay my hand upon much of a very definite character—except as to methods of investigation—save in regard to one point. I have some reason to know that about the year 1860, at any rate, there was nothing more volcanic, more shocking, more subversive of everything right and proper, than to put forward the proposition that as far as physical organization is concerned there is less difference between man and the highest apes than there is between the highest apes and the lowest. My memory carries me back sufficiently to remind me that in 1860 that question was not a pleasant one to handle. The other day I was reading a recently published valuable and interesting work, 'L'espèce humaine,' by a very eminent man, M. de Quatrefages. He is a gentleman who has made these questions his special study, and has written a great deal and very well about them. He has always maintained a temperate and fair position, and has been the opponent of evolutionary ideas, so that I turned with some interest to his work as giving me a record of what I could look on as the progress of opinion during the last twenty years. If he has any bias at all, it is one in the opposite direction to that in which my own studies would lead me. I can not quote his words, for I have not the book with me, but the substance of them is that the proposition which I have just put before you is one the truth of which no rational person acquainted with the facts could dispute. Such is the difference which twenty years has made in that respect, and speaking in the presence of a great number of anatomists, who are quite able to decide a question of this kind, I believe that the opinion of M. de Quatrefages on the subject is one they will all be prepared to endorse. Well, it is a comfort to have got that much out of the way. The second direction in which I think great progress has been made is with respect to the processes of anthropometry, in other words, in the modes of obtaining those data which are necessary for anthropologists to reason upon. Like all other persons who have to deal with physical science, we confine ourselves to matters which can be ascertained with precision, and nothing is more remarkable than the exactness which has been introduced into the mode of ascertaining the physical qualities of man within the last twenty-five years. One can not mention the name of Broca without the greatest gratitude; I am quite sure that, when Professor Flower brings forward his paper on cranial measurements on Monday next, you will be surprised to see what precision of method and what accuracy are now introduced, compared with what existed twenty-five years ago, into these methods of determining the facts of man's structure. If, further, we turn to those physiological matters bearing on anthropology which have been the subject of inquiry within the last score of years, we find that there has been a vast amount of

progress. I would refer you to the very remarkable collection of the data of sociology by Mr. Herbert Spencer, which contains a mass of information useful on one side or the other, in getting towards the truth. Then I would refer you to the highly interesting contributions which have been made by Prof. Max Müller and by Mr. Tylor to the natural history of religions, which is one of the most interesting chapters of anthropology. In regard to another very important topic, the development of art and the use of tools and weapons, most remarkable contributions have been made by General Lane Fox, whose museum at Bethnal Green is one of the most extraordinary exemplifications that I know of the ingenuity, and, at the same time, of the stupidity of the human race. Their ingenuity appears in their invention of a given pattern or form of weapon, and their profound stupidity in this, that having done so, they kept in the old grooves, and were thus prevented from getting beyond the primitive type of these objects and of their ornamentation. One of the most singular things in that museum is the exemplification of the wonderful tendency of the human mind when once it has got into a groove to stick there. The great object of scientific investigation is to run counter to that tendency.

Great progress has been made in the last twenty years in the direction of the discovery of the indications of man in a fossil state. My memory goes back to the time when anybody who broached the notion of the existence of fossil man would have been simply laughed at. It was held to be a canon of paleontology that man could not exist in a fossil state. I don't know why, but it was so; and that fixed idea acted so strongly on men's minds that they shut their eyes to the plainest possible evidence. Within the last twenty years we have an astonishing accumulation of evidence of the existence of man in ages antecedent to those of which we have any historical record. What the actual date of those times was, and what their relation is to our known historical epochs, I don't think anybody is in a position to say. But it is beyond all question that man, and not only man, but what is more to the purpose intelligent man, existed at times when the whole physical conformation of the country was totally different from that which characterizes it now. Whether the evidence we now possess justifies us in going back further or not, that we can get back as far as the epoch of the drift is, I think, beyond any rational doubt, and may be regarded as something settled. But when it comes to a question as to the evidence of tracing back man further than that—and recollect the drift is only the scum of the earth's surface—I must confess that to my mind, the evidence is of a very dubious character.

Finally, we come to the very interesting question—as to whether, with such evidence of the existence of man in those times as we have before us, it is possible to trace in that brief history any evidence of

the gradual modification from a human type somewhat different from that which now exists to that which is met with at present. I must confess that my opinion remains exactly what it was some eighteen years ago, when I published a little book which I was very sorry to hear my friend, Professor Flower, allude to yesterday, because I had hoped that it would have been forgotten amongst the greater scandals of subsequent times. I did there put forward the opinion that what is known as the Neanderthal skull is of human remains, that which presents the most marked and definite characteristics of a lower type—using the language in the same sense as we would use it in other branches of zoology. I believe it to belong to the lowest form of human being of which we have any knowledge, and we know from the remains accompanying that human being, that as far as all fundamental points of structure were concerned, he was as much a man—could wear boots just as easily—as any of us, so that I think the question remains pretty much where it was. I don't know that there is any reason for doubting that the men who existed at that day were in all essential respects similar to the men who exist now. But I must point out to you that this conviction is by no means inconsistent with the doctrine of evolution. The horse, which existed at that time, was in all essential respects identical with the horse which exists now. But we happen to know that going back further in time the horse presents us with a series of modifications by which it can be traced back from an earlier type. Therefore, it must be deemed possible that man is in the same position, although the facts we have before us with respect to him tell in neither one way nor the other. I have now nothing more to do than to thank you for the great kindness and attention with which you have listened to these informal remarks.

THE STORY OF AUTONOUS.

By Prof. WILLIAM HENRY HUDSON,
STANFORD UNIVERSITY.

IF any one in these days condescends to read that first favorite with the youth of bygone generations, 'Robinson Crusoe,' he will be aware that, disregarding its more subtle meanings and the allegorical intention upon which the author himself laid so much stress, we may consider the narrative as a detailed study of self-help. In our actual world, we depend to an extent which we seldom appreciate upon social environment, organization, the labors of others and the accumulated culture-capital of the past. Well, DeFoe takes a man of an eminently sturdy, courageous and practical type, casts him upon a desert island and there leaves him to shift for himself. Supplies which he manages to rescue from the ship give him a fund of materials to start with; but henceforth he has nothing to rely upon save his own head and hands. To follow this plain and simple hero in his successful struggle against seemingly overwhelming odds does not fall within our present plan. But the issue shows how, by his own unaided exertions, an individual may reconstruct for himself a great many of those conditions of comfortable living which we are apt to assume to be impossible without the cooperation of others; and thus the mastery of man over his fate is vindicated—though it would certainly go hard with most of us if we were thrown into Robinson Crusoe's position.

Rousseau, who was the first to point out the educational significance of DeFoe's book, desired that Emile, in studying it, should examine the mariner's behavior, "to try to find out whether he omitted anything, and whether anything could have been better done." Questions of this kind may often have been in the reader's mind and are useful in bringing out the admirable art exhibited in every episode and detail. But there is another question which will, perhaps, occur to some, and which at once carries us beyond DeFoe's own narrative into a very wide field of speculation. Robinson Crusoe was already a mature man when he was cast away; he was in full possession of the stored-up resources of civilization; his mental powers were well developed; he brought a man's strength and training to bear upon the problems of his life. The theme of his story is, therefore, on the philosophic side, after all, a relatively simple and narrow one. But now let us suppose for a moment that he had been cut adrift from all his social moorings before education began—before, even, consciousness had awakened to a sense

of outward things. What would have happened to him then? Would he necessarily have perished? Or, if he survived, would he have grown into anything better than a brute? What would the course of his life have been? And can we conceive that, lacking all influence from without, all family and social intercourse, all idea of human traditions as embodied in manners, customs, institutions, books, he would ever, mentally and morally, have reached the full stature of a man?

I am not going to attempt to discuss these questions from the standpoint of modern science, or in connection with the recent controversies of the evolutionists. My purpose is simply to give some account of an extremely crude, but none the less quaint and interesting old book, in which, under the thin guise of a story, an effort is made to answer them. The little volume is exceedingly rare and is probably unknown, even by name, to most readers of these pages. An outline of its contents may, therefore, prove entertaining, if not exactly instructive.

I must first dismiss some details of a bibliographical character. Referring, in his Memoirs, to his one-time tutor, John Kirkby, the historian Gibbon speaks slightingly enough of a work of his which, aspiring 'to the honors of a philosophical romance,' had brought him a certain measure of fame. Gibbon cites it by a brief title only—'The History of Automathes'; but its full title, after the fashion of the time, set forth a regular programme, or summary, of the volume—"The Capacity and Extent of the Human Understanding, exemplified in the extraordinary case of Automathes, a young nobleman, who was accidentally left in his infancy upon a desert island and continued nineteen years in that solitary state, separate from all human society." The book, which bears date 1745, was thought by Gibbon to be a kind of compound of 'Robinson Crusoe' and an Arabian story, 'The History of Hai Ebn Yockdan.' On closer examination, however, it turns out to be a barefaced plagiarism from a much smaller work, issued anonymously nine years before—"The History of Autonous: Containing a Relation how that young Nobleman was accidentally left alone in his Infancy, upon a desolate Island, where he lived nineteen years, remote from all human Society, till taken up by his Father; with an Account of his Life, Reflections and Improvements in Knowledge during his Continuance in that Solitary State. The whole as taken from his own mouth." It is almost incredible that, even in an age when literary frauds were more frequent and less easily detected than at present, Kirkby should have dared to publish his own book as original; but he never appears to have been taken to task for his conduct, nor, indeed, do readers and critics of 'Automathes' seem to have known or cared anything about 'Autonous.' But, from a pretty minute comparison of the two works, in the library of the British

Museum, I am able to state that where Kirkby's dependence upon an earlier writer is referred to at all—as in the article in the 'Dictionary of National Biography'—the case for plagiarism is not put half strongly enough. Kirkby did not merely borrow hints, ideas, episodes; he stole the entire book, adding, expanding and slightly rearranging in places, but adhering to the plan of his predecessor and sometimes retaining his actual phraseology for paragraphs and pages together. To illustrate these statements would necessitate the reproduction of a number of lengthy passages, and space cannot here be spared for such an undertaking. I have said this much to make clear to any reader of Gibbon's Memoirs, or Scott's fragment of autobiography, why I now disregard Kirkby's work and confine myself to what was evidently its immediate source and model.*

The writer of the 'History of Autonous,' then, opens his narrative by telling us how he became acquainted with that young nobleman, at the University of Eumathema, in the Kingdom of Epinoia. He is invited to take a short pleasure trip with him in his barge up the river. It is on this occasion that Antonous entertains his guest with the story of his life.

His father, Eugenius, chief of one of the most ancient houses in the kingdom, had married Paramythia, a young lady of 'quality nothing inferior to himself.' About the time of Autonous's birth, a rebellion broke out in Epinoia. It was promptly quashed; but, through 'the underhand Dealing of some ill-designing Persons,' enemies of Eugenius, he was arrested, tried and found guilty of treason. He was, therefore, condemned to banishment and the forfeiture of his estates.

With his wife, child and a couple of servants, the unfortunate nobleman sets sail for a distant land; the ship goes to pieces in a storm, and all on board perish, except Eugenius, Paramythia and the baby, who are cast upon an uninhabited island. The father manages, like Robinson Crusoe, to save some necessaries and a number of miscellaneous articles from the wreck, and, with these, a little dog, which afterwards plays an important part in the story.

On examination of the island, it is found that, most fortunately, there are no 'noxious animals' or venomous creatures there, 'but multitudes of goats, deer and fowls of every kind,' furnishing abundance of provision. Eugenius hunts with bow and arrow and presently builds a cottage, in a grove of trees and within view of the sea, in the hope, like Enoch Arden, of sooner or later sighting a chance sail. But the

* 'Autonous' occupies 117 pages; 'Automathes,' 284. The difference is due partly to Kirkby's tendency to amplification, and partly to a long critical introduction containing a good deal of political disquisition, not at all to the point, and incorporating the machinery of a manuscript discovered in a cylinder, which adds neither to the clearness nor to the interest of the subsequent narrative. (Of course, as we do not know who wrote 'Autonous' there is the chance that this was a first draft of the later and longer book, by Kirkby himself. But this does not seem likely.)

island lies out of the ordinary course of vessels; wherefore, but for a merciful Providence, the little party would have perished one by one—a catastrophe which, says Autonous with refreshing simplicity, 'wou'd have depriv'd me of the Opportunity of thus telling my Story.'

Herbs, roots and 'limpid water,' with the produce of the chase, therefore constitute their fare; and their greatest pleasure, animal wants being satisfied, is found in 'the usual Resort of Persons in affliction'—namely, 'Devotions and Spiritual Exercises.' Incidentally, we are here treated, in the characteristic style of the eighteenth century, to a brief disquisition on 'Nature' and 'Luxury'; but this may be skipped as having nothing directly to do with our narrative. By-and-by, poor Paramythia, unable to endure the hardships of the new life, falls sick and dies. For a time Eugenius is heart-broken. Then he returns to the care of the helpless baby, and, to obtain milk for him, domesticates a hind. By mere power of imitation, Autonous learns from the fawn to take nourishment directly from the animal, while by watching his constant companion, the dog, he soon begins to dig up edible roots.

Things in this way are prepared for the real commencement of Autonous's story. The death of his wife preys upon the mind of Eugenius; he grows restless and spends his time in vain attempts to devise some means of escape. One unusually clear day, he fancies that he can detect a faint streak of land upon the far horizon. Upon this, he patches up the ship's boat, which had been cast ashore, to start out by himself upon a voyage of discovery. Once more Fate shows herself against him. The boat, drawn into a swift current, is carried to another island and afterwards washed away. Eugenius saves himself, but father and son are now separated.

Autonous is not quite two years old when this happens. For nineteen years he lives entirely alone; at the expiration of which time both he and Eugenius are picked up by a stray ship of war and carried back to Epinoia. The latter's innocence is forthwith made clear to the world, and all ends happily. But, it may well be asked, in what condition is Autonous himself, after this long period of isolation? The good people of Epinoia are surprised, as we in our time are surprised, to find him acting more like 'a Philosopher than a Savage.' How had such an amazing result been brought about?

Looking back into the obscurity of his strange past, Autonous declares his first consciousness to have consisted in the simple sense of being in the cottage his father had built. He had, of course, no recollection of anything before his arrival on the island, or of his father and mother; but he remembered, vaguely, taking 'little journeys' from the cottage, the guidance or barking of the dog keeping him from going altogether astray. But he retained no image of the hind by which he had been suckled, for that portion of his experience

belonged to the life of instinct and sensation merely. When he awoke to a realization of himself and the outer world, he found himself living, as a matter of simple habit, on roots and fruit, to which he had gone, apparently, in imitation of the animals and birds. "During this Part of my Life," he says, "my Rational Faculty laid [*sic*], as it were, dormant within me. I never made the least Reflection upon my Condition, nor turned my Thoughts to the Contemplation of anything about me." Such, Autonous conceives to be "the thoughtless State of all Persons for the greatest Part of the Childhood, while the Mind is furnishing itself with Instruments to work with."

With Autonous, however, this condition naturally lasts longer than with ordinary children, who from the beginning are associated with older people and have the advantage of the education directly and indirectly given by such intercourse. But it happens that, while all children are more or less inquisitive, Autonous is particularly so; and endowed, moreover, with unusual power of response to the stimuli of surroundings, he soon begins to gather in, from all sides, the rough materials of thought.

Happy accident first stirs him to 'serious Reflection.' One exceedingly hot day he strays 'something further than ordinary' from his cottage; and going to a small lake to quench his thirst, he is surprised 'with the appearance of a creature in the Lake' of a shape very different from anything he 'ever had seen,' which, as he stoops to the water, seems to leap upward to him, as if with a design to seize him. He flies in terror to a neighboring wood; but after a time, his thirst returning, he takes courage again, goes back to the lake and repeats the experiment; but only with the same dreadful result. This, Autonous explains, was the first time he had ever seen his reflection in smooth, still water, having previously drunk from fountains, or from shallow and rapid streams. He is so terribly frightened that for some weeks he hardly dares to leave the cottage, while his sleep is broken by 'fearful Starts and Dreams.' Little by little, the horror wears off, but other effects do not. He has been aroused to a 'sense of myself,' and begins to ask—a trifle prematurely, we fancy—'What am I? How came I Here?' These questions are rather too definitely put, but the incident and its consequences certainly foreshadow in an interesting way some of the speculations of recent anthropologists on the part played by shadows and reflections in the growth of the idea of the other self, or soul. Autonous's thoughts, however, take a somewhat different turn. He later discovers a 'crystal Brook,' in which, to his astonishment, he observes another sky, another dog, another world. By examination, he finds that there is, none the less, a real bottom to this brook; and thus he learns the secret of 'natural Reflection.' Remembering his former fright, he also studies himself very carefully in the water, and concludes

that he had been alarmed by his 'own Image and Resemblance.' From this, he makes a sudden leap into theories concerning himself and the manner in which he and the dog had got to be where they are; and recalling what he had already noted of the 'usual method by which all other living creatures propagated their likes,' he sapiently infers that their own coming into the world must have been after the same fashion. All this must have happened, he believed, when he was about ten years of age.

The notion that he must have had a beginning somewhere, and that, though he was now living entirely alone, he was really in some inscrutable way linked to his kind, is now confirmed by an examination of his cottage, which up to the present he has accepted uninquiringly and as a mere matter of course. Comparing it with the dwellings of the beavers on the lake-shore, he guessed that it must have been built by predecessors of his own and arranged for their comfort and protection. The remains of one of the ship's boats, decaying on the strand, are, moreover, caught up in his speculation, suggesting transportation, and hinting, if at first rather vaguely, at a great human world out of which he has been cast. "But what," exclaims Autonous, "is the Beginning of Reason but the Beginning of Sorrow to creatures whose Reason can only serve to discover their Wants and Imperfections to them?" His tranquillity—the tranquillity of mere animal existence—is at an end. His mind broods continually over the 'Thoughts of Human Society,' without which he feels there can be no happiness for him, or even peace. He watches the birds and beasts, and envies their social lot. Had the boat been in sufficient repair, he feels that he might even have started off in the wild hope of finding somebody somewhere. "So strong an Inclination has Nature implanted in us for the Conversation of our Fellow-Creatures, in order to communicate our joys and griefs and sympathize under one another's sufferings."

Despite this heart-hunger, Autonous now enters on the high-road of intellectual progress. He begins to observe with close attention the growth of trees, grass and flowers, and the dependence of all animal life upon the fertility of the soil. Thus far we can without much difficulty keep up with him. But from this point he goes forward with such leaps and bounds that we are left almost breathless in our efforts to follow. For now he notes how the 'successive Renewals of Nature' exactly correspond with 'the Motions of the Sun,' and the agreement between the phases of the moon and the tides. The revolutions of 'the lesser heavenly luminaries' also become the subject of his 'nocturnal Contemplations'; moreover, he studies the rainbow, and discovers the 'necessity of Rain and the solar Heat' to 'ripen the Fruits of the Earth.'

Nor are these the only, or the most astonishing, results of his

solitary cogitations. He considers 'the admirable Structure of the Bodies of every Species of Animal' within his reach; is struck by the detailed adaptations of their faculties to the various conditions of their lives; and soon learns to appreciate their 'Art and Foresight' in the preservation of self and young. "In fine," he declares—and by this time we are, of course, fully aware of the drift of his thought, "I beheld the marks of Wisdom wherever I cast my Eyes. An universal Harmony and Dependence appeared through all the Parts of Creation, and the most neglected Things, when duly examined, were not without their manifest use; and I was everywhere surprised with an apparently wise Design, where the least Design was expected."

Had our young Natural Philosopher, we ask, been reading the 'Essay on Man' on the sly? His 'universal Harmony and Dependence' is only the 'great chain of being' over again, and when he further informs us that 'from the works of Nature and Providence' he was inevitably 'led to the knowledge of the First Mover,' he is simply explaining how he looked 'through Nature up to Nature's God.' In fact, the religious development of Autonous, solitary and untaught, furnishes us with an interesting illustration of the early eighteenth-century argument from design. The familiar discussion follows of 'beauty' and 'fitness' as evidences of 'some intelligent Agent,' who is easily shown to be at once all-wise, all-powerful and all-good. All this, indeed, belongs to the 'mere Light of Nature.' But we have only to remember the common eighteenth-century view of the relation of natural and revealed religion to appreciate the importance of the step which the lonely youth had now taken.

We may observe, in passing, that the conditions of life on the island are highly favorable to an optimistic philosophy. Dwelling in a veritable little Garden of Eden, where general peace prevails and the red tooth and claw of nature are seldom shown, Autonous has no difficulty in believing in a Providence both omnipotent and benign. This is surely the best of all possible worlds, he might have said, with Leibnitz and Dr. Pangloss; and there is no rude fact to meet him at the first turning of the eye and shake his whole scheme to its foundations. But what if Autonous had been thrown among birds and beasts of prey? Our author has simplified his task by not raising that question.

Meanwhile the youth is gaining ground in other directions. From what, in the true style of his time, he calls 'the harmonious Chanting of the feathered Tribes,' he infers that speech is the 'method used among men to communicate their minds in conversing one with another'; and from the *ignis fatuus* and the glow-worm he learns something, though not as yet much, of fire and light. He also gets a little practical experience well worth recording. A couple of bottles, saved by his father from the wreck, have been standing all these years

untouched on a shelf in the cottage. By accident one is broken and Autonous tastes the contents, which prove to be 'a most delicious and heady sort of Wine.' He is delighted, straightway opens the other bottle, and, sad to relate, gets drunk. Having quite by himself discovered the nature of God, he now, quite by himself, discovers the nature of intoxication. It is by this time apparent, I think, that Autonous is an unusually wise young fellow. Finding how ill the potations make him, he very properly throws 'the remainder of this beautiful Liquor, Bottle and all, into the Sea.'

During the feverish affection brought on by his bout, he walks a good deal at night, and is lucky enough (for thus, in the order of Providence, does good grow out of evil) to see the moon in eclipse. This phenomenon fills him with 'exceeding Amazement,' and for a time he does not know 'what to make of it.' But he is not the youth to be long puzzled over a little thing like an eclipse. Presently an eclipse of the sun occurs—seemingly for his personal benefit. Upon this, he sets to work in earnest, and soon clears up all the difficulty. Considering how long it took for the race at large to learn the real nature of an eclipse, we may regard this as one of our philosopher's most remarkable performances.

His continued study of animals—'some of which,' as he sagely remarks, 'afforded an excellent Pattern of Prudence and Industry, for the Imitation of Men'—leads to no less important results. Observing the beavers, in particular, he remarks 'with what true Policy every distinct Community' is 'governed under its peculiar Monarch'—the only wonder being that he did not infer from his investigations the principles of the Hanoverian Succession. Their methods of building houses and dams, of laying up supplies for the winter and of gnawing down trees with their teeth, specially delight him; and from their example, and that of the dog, he learns to swim; thus becoming acquainted with 'fresh matter for wonder' in the shape of fish. He now devotes a good deal of time to the contents of the cottage, and takes note of 'two or three knives and forks,' and a hatchet, the sharpness of which suggests a use similar to that which the beavers made of their teeth in cutting trees. Hammer and a bag of nails, a rusty sword, a bow, a silver tankard and some other utensils are also discovered by him, but these he confesses that he was never 'so ingenious' as to turn to account. But he learns the color and malleability of several metals, and as, by hacking at various articles with the chopper, he deprives them 'of the forms in which he found them,' so he concludes, by one of his rapid processes of reasoning, that 'they must by some like Operation'—by some human power and effort, he presumably means—'have been first wrought into the same.'

In this part of his story, Autonous of course depends a good deal

on the then familiar theory that all art arose from observation and imitation of nature—a theory which often appears in the literature of the time and which will be at once recognized by readers of Dryden and Pope.*

A large chest and a couple of boxes, hitherto neglected, are now ransacked by our inquiring young friend. Much of their contents merely puzzles him; but he is highly pleased to discover books, white paper, some lead-pencils, pens, an inkstand, a magnifying glass, a case of mathematical instruments, a fan, a small looking-glass, a gold watch and a snuff-box. These form his playthings for some time and, little by little, he gets to understand the properties of glass and of the magnifier, the peculiar properties of which he finds to be due 'to convexity.' But, above all, he is enraptured by the fan, on which is painted a landscape, with several figures in his 'own shape.' Two in particular rivet his attention—'a comely Pair,' who seem 'wholly taken up with the Contemplation of each other.' They are 'seated under the Umbrage of a spreading Beech,' and he notes that 'their whole Bodies, save their Faces and Hands,' are 'hid from Sight under much the same sort of Coverings' as he had found 'in the Chest and Boxes.' One of these figures he concludes to be the male, the other the female; and upon the latter he gazes 'with more than common delight,' very gallantly, as well as very properly, concluding 'that the sex to which she belongs must be a masterpiece of nature's workmanship.' But the growth of tender sentiment does not here interfere (as it is occasionally known to do) with severer studies. Autonous—though he confesses that this may be judged 'quite above my capacity'—becomes 'in some Degree' acquainted with the pencils and paper, the books and instruments; and by dint of pothering over a volume of mathematics he gleans 'the Principles of that Science,' becoming quite familiar with the use and form of figures. All this happens about his fifteenth or sixteenth year, about which time he begins to make various improvements in and about the cottage, laying out the garden in imitation of the landscape on the fan, repairing the fences, clearing bushes and shrubs, and generally substituting order for confusion.

All this while Autonous is busy with the 'Contemplation of himself' and ripens apace into a metaphysician. He soon distinguishes between mind and matter, the former of which he recognizes as the 'only and proper self,' and by watching closely the procedure of the mind, actually reaches some notion of the doctrine of the association of ideas. Sleep, with its phenomenon of unconsciousness and dreams, also engages his attention, and while he is occupied with these mysterious matters, it happens that his dog is killed by a beaver. This was Autonous's first

* See 'Annus Mirabilis,' Sec. 155; 'Essay on Man,' Epistle III.

introduction to death. Reasoning over this occurrence, he advances step by step to the thought of dissolution and the immortality of the soul. We may suppose that he is really grieved over the loss of his faithful companion, but of this he says very little. And we have heard of other philosophers who, preoccupied with such questions as God, freedom and immortality, have had small energy to spare for ordinary mundane affairs.

Having followed Autonous in some detail up to this point, we shall probably express no great surprise when we learn of his further achievements, practical and intellectual. Passing over such feats as the invention of a sun-dial and the fashioning of a quadrant, we come at length to an important discovery which is made by simple accident. One day, while he is chopping down a tree, his hatchet strikes fire, some chips are ignited and he burns his fingers. Of course, he goes to work to experiment on this new element, fire, and in his pursuit of knowledge under difficulties, not only nearly burns down his cottage, but does, in fact, destroy a good deal of property and a number of animals. In this way he learns very effectually that fire, though a good servant, is a bad master. Indirectly, another consequence follows. His alarming adventure rather oddly gives him 'the first sad experience of the severe Lashes of a self-condemning Conscience'; a trouble compared with which he finds that all his other sorrows were as nothing. With such a youth as Autonous, the remote results of this discovery may be easily anticipated. An 'inward Sense of guilt and shame' arises; he begins to realize the 'natural Depravity and Perverseness' of his temper; and a new idea—the idea of Duty—takes shape in his mind. He begins to reflect on the 'great Disorders of the Soul,' of which other creatures on the island seem to know nothing, and comes slowly to feel that the world is 'nothing else but a black scene' of 'wickedness and impiety.' Having thought out for himself the principles of natural religion, our young theologian is, as we see, on the high-road to Christianity. Man by nature, he concludes, is in an 'indigent and imperfect State,' and is evidently so placed that he may be kept in a due sense of dependence on God. Hence the need of 'some Supernatural means' by which God must have made known His will to men; hence the inevitableness of prayer and supplication; and hence the necessity of a future life, with rewards and punishments, as the logical completion of the scheme of salvation.

The long course of Autonous's education* is now complete, and there is nothing left for him but to be rescued and brought into human

* It will be observed that by a striking oversight (whether intentional or not I cannot say) not a word is said about the question of language. Autonous clearly did not evolve this by himself, though, as we have seen, he had arrived at the idea of intercourse through speech. He must, therefore, on his return to civilization, have been in the condition of a dumb philosopher unable, till taught, to put his thoughts into language.

society. He is now, we remember, at the end of his twenty-first year, and our obvious comment is that he is well advanced for his age. With his return to civilized life, the story properly closes; but the author of the second work—the 'History of Automathes'—adds something on his own account to clinch the moral. The immense progress which the youth was able, by himself, to make was not, we are asked to recollect, due to inward natural capacity. Had he been thrown entirely on his own resources after his father's departure—had he, that is, been deprived of the various aids his father left behind him—he would inevitably have perished, or, surviving, have sunk to the level of the brutes. In such a condition the race at large would have remained in default of assistance from without. Hence, argues the author, civilization must have depended, at the first, upon supernatural revelation. Particularly must this have been the case, he further insists—though the history of Autonous (or Automathes) hardly sustains the contention—with all religious knowledge. We must, therefore, assume a primeval revelation to all men, shadows and survivals of which are to be found in heathen mythologies and extra-Christian speculations.*

It is almost a pity, we are tempted to say, as we lay the strange little book aside, that Autonous was rescued just when he was. Having on his own account discovered so many things which it has taken humanity thousands of years to find out, he might, had he been left alone, have pushed his researches into who knows what fresh domains of science, theoretical and applied. Or perhaps, it may be suggested, his achievements were, after all, due to his peculiar conditions—to abandon a child on an uninhabited island may, in other words, be the very best way of developing his faculties. In an age which has already gone wild over educational theories, some one may be glad to take this idea under consideration.

More serious comment is unnecessary. Our brief outline will have sufficed to show the extravagance of Autonous's story, the clumsiness of its machinery and its general lack of plausibility. Its further weakness as a culture-study—the introduction of too many human aids to mental growth—will also be equally apparent; though this is probably referable to the author's realization of the impossibility of getting on without such assistance, as testified in the actual case of the then famous Wild Boy of Germany. But the little book does open up a number of fascinating questions, and, in closing it, we may well ask why, in these days of scientific and psychological fiction, some novelist in search of fresh material does not try his hand on what is surely a not uninteresting or unfruitful theme.

* Compare Dryden, 'Introduction to Religio Laici.'

THE ECONOMIC LIFE OF FRANCE.

By Dr. EDWARD D. JONES,
UNIVERSITY OF WISCONSIN.

THE country of France, by reason of its position, has been forced into prominence in the life of Western Europe. The nation is surrounded by powerful peoples of diverse types, and because of its central location has perhaps developed a more cosmopolitan culture than its neighbors. The French people are separated most completely by the natural features of their boundaries from those races most closely resembling them. The road is open where the antagonism of types is greatest. The continental position of France has involved her in the troubles as well as in the reforms of her neighbors, and has opened the door to conquest, but left it open to invaders.

The internal geography of France shows no such extensive mountainous regions, or other sharp geographical divisions, as exist in the British Islands. The vanquished races of France have therefore not been able to retain their separate nationalities as completely as have the Scotch, Welsh and Irish. The British Islands are open on all sides to the sea, and with their abundant harbors have trained up a nation of sailors and colonists to carry Anglo-Saxon culture around the world. France is compact in outline, and though she has much coast, lacks good harbors. The activity of the national mind has been turned inward. This betrays itself in the intense patriotism of the people, in the influence exerted by the national capital and in the failure of France as a colonial power.

The region included in European France comprises about one two-hundred-and-fiftieth of the land of the earth, and about one eighteenth of Europe. The area is 204,150 square miles, or about twice that of the British Islands. The water boundaries are as follows: Mediterranean Sea coast, 395 miles; North Sea, Straits of Dover and English Channel, 572 miles; Atlantic Ocean, 584 miles.

The boundary between France and Spain coincides, for the most part, with the crest of the Pyrenees Mountains. It is, from the economic point of view, a veritable 'wall of separation.' Indeed, it is a well-nigh impassable boundary, as may be seen from the Spanish proverb describing the passes of these mountains—"A son would not wait there for his father." Communication between France and Spain is carried on by means of railways, near the Mediterranean and Atlantic coasts, and by water. The French slope of the Pyrenees is a pas-

toral country. Because of the regularity of the mountain chain this region affords an unrivaled opportunity to study social structure as influenced by altitude. In the upper mountain valleys the shepherds group their homes into clusters of houses. From them the flocks are led out to pasture, for weeks at a time, on the highest slopes that support vegetation. In these altitudes there are no true villages except where a military station and a custom house draw a few troops and officers together, or where springs have given rise to water-cures. No minerals have drawn thither a mining population. There is nothing but water, forest and pasture. Ten or twelve miles down the mountains the upper valleys open into larger ones. At these outlets are the mountain market towns. These mark the ends of the railway spurs, and from them the shepherds procure their supplies. Another twelve miles down, and the level plains are reached. Close to the openings of the lower valleys the railway branches join to form railway centers, and towns of considerable size have grown up to transact the business between the mountain and the plain.

Between Italy and France the highest portion of the Alpine range intervenes. Over these mountains the Roman legions and the soldiers of Hannibal toiled. But here has been achieved one of the most striking of the conquests of man over nature. The Mount Cenis railway tunnel route, which pierces these mountains, carries the modern tourist from the Rhône to the cities of the upper Po Valley in a few hours. The French slopes of the Alps support only a scant population of mountaineers. Many of these migrate in winter to the plains in search of work, or, housed for long months in their frozen valleys, devote themselves to household industries or to reading and self-education. It is a matter of general remark in the towns of the Rhône Valley that the schoolmasters come from the mountains.

Switzerland and France are divided by the Jura Mountains, but through the Pass of Belfort a large commerce finds passageway. The Jura present a semi-Swiss character, though, compared with the Alps, they are less lofty, differ in geological structure, and receive a greater rainfall. They are noted for luxuriant pastures and dense forests. The chief industries are cattle raising and the manufacture of butter and cheese. In the latter business the co-operative form of industry largely prevails. The rivulets of the mountains afford numerous small water-powers, which are employed in wood-working and the manufacture of watches. Besançon is the watch market of the region. From the timber are made casks for the wine merchants of Champagne.

North of the Jura lie the Vosges Mountains, along the crest of which the Germans have placed their boundary for some distance. The slopes of the Vosges toward Alsace are steep; those toward France are gradual. The rains which water the region come from the west.

The French slopes are, therefore, forest-covered, while in Alsace the lower hills are devoted to the vine, and the upper to grain.

North of the Vosges the boundary line across the plateau of Lorraine before plunging into the rugged forests of the Ardennes. From the latter it finally emerges upon the coast plains to form the Belgian frontier. Between Belgium and France the political boundary is purely arbitrary. There is not an economic boundary, but rather a hive of industry between the two peoples. The political grouping does not correspond with that of race or language.

This hasty review of the land boundaries of France has embraced the consideration of five distinct mountain regions. The general relief of France is less uniform than that of Prussia or Russia, but more uniform than that of Spain or Italy. Forty-six per cent. of French territory is classed as mountainous. Nevertheless, variations in altitude are softened, and there is in France a great deal of what might be called transitional country. The highest mountains are fortunately upon the borders, and but two other regions of broken country need to be considered.

Let us, then, turn from the boundaries to the internal geography of France, and first of all complete our enumeration of mountain areas by considering the Central Highlands and Brittany.

In the south central part of the country there exists an extensive semi-barren plateau of highly fractured, crystalline, eruptive and volcanic rocks. It slopes sharply to the Rhône on the east, more gently to the Garonne River on the southwest, and to the Loire River on the north. The rocks of this region are so fractured that the rains which fall upon them sink almost immediately out of sight. The country is graced by no transparent mountain lakes or sparkling rivulets. Water must be carefully collected in cisterns or laboriously transported from lower levels. Lack of moisture and the forbidding character of the rock make the pastures so meagre that only sheep and goats can be supported. From them is won the wool which supports a household industry, and from their milk cheese is made. In the eleventh century the cheese of the little village of Roquefort was put away in a rock cave to 'ripen'. It was soon found that this cheese possessed remarkable excellence of flavor. Its fame spread widely, and a new use was from that time found for the caverns which abound in the Cévennes Mountains. The demand was so great that 'bastard caverns' were excavated in the hope of securing the coveted flavor, but the cheese in them has never acquired the properties of real Roquefort. The western slopes of the Central Highlands receive a greater rainfall and possess a more durable pasturage and a more dense population than the eastern. Auvergne is celebrated as the home of sharp cattle merchants, as well as of the peddlers of France. The central plateau has

been aptly termed, by the French, a 'pole of divergence,' from which the population migrate in all directions, but especially toward the northern plains, within which lies the pole of attraction.

The peninsula of Brittany, with its backbone of crystalline rock, may be counted as a semi-mountainous region. It much resembles the English peninsula of Cornwall. But Britanny contains no attractive mineral deposits, so it has longer remained a world apart than has Cornwall, and it still shields many ancient prejudices and practices. The interior districts are, in analogy with Cornwall, of inferior, unattractive character, but agriculture and the dairy industry are profitably carried on along the coast. This region is the only one in France abounding in good harbors. The sea is the mainstay of a large part of the population. The fisheries yield herring, sardines, mackerel, lobsters and oysters. The four departments which compose Brittany furnish the merchant marine of France with one-fifth of its sailors, while eighty-two other departments supply the remainder.

The portions of France still remaining to be treated may be grouped into river-valley and coast regions. Beginning with the southeast, we have, along the Mediterranean coast, the sea of ancient Phœnician, Greek and Roman colonies. This coast is divided into two very distinct portions, separated by the mouths of the Rhône River. The eastern section comprises the Mediterranean foot-hills of the Alpine system. It is a region of bold cliffs and promontories. It contains several excellent harbors, among which are Marseilles, Nice and Toulon, the last being the first naval station of France. This high, well-drained, romantic coast-land, forming part of the Riviera, is the most popular resort of Europe. Here are Cannes, Nice, Menton and the little principality of Monaco, possessing independence to no better purpose than to license the gaming tables of Monte Carlo. A little distance from the coast are the romantic islands called by the ancients the Islands of the Hesperides. To the west of the Rhône are to be found low, sandy plains, which stretch away to the foot of the Pyrenees. Toward the coast these give way to malarial swamps. Over these extensive marshes roam herds of half-wild cattle and horses, pastured in the mountains in summer, and brought to the coast in winter, just as are the wild bulls that inhabit the swamps about the mouth of the Guadalquivir in Spain. The inhabitants of the region have to contend with an unhealthy climate. Agriculture implies an expensive system of drainage. The wind-mills used for pumping give to the landscape a striking resemblance to Holland. Along the coast bay salt is evaporated by solar heat. The cities, because they require firm ground for their location, are of necessity situated a long distance inland. This fact has prevented Languedoc from being a commercial country.

Between the Alps and the Central Highlands intervenes the valley

of the Rhône, which forms the highway across western Europe from the Mediterranean to the northern plains. The Rhône Valley is a narrow one. In the south the culture of silk-worms forms a special industry. At Lyons the manufacture of silk is located. Between these two regions there are detached areas suitable for agriculture. The Rhône is a beautiful stream of transparent blue water and swift current. The Saône Valley forms the northern continuation of the Rhône. It is transitional in character, having in the east the characteristics of the wooded Jura, in the west those of the parched Côte d'Or, and of the vineyards where Burgundy and Champagne are produced. Here also are blended the races and dialects of the north and south of France.

In the southwestern corner of the Republic spreads out the valley of the Garonne. The winds from the Atlantic which blow up this valley are caught as in a sack, and a rainfall is precipitated, which reaches each of the tributaries of the Garonne. Because of this, the river is subject to great variations of depth. It is not amenable to commercial uses, and has been paralleled by a canal. The region about the lower course of the river is devoted to wine producing, the product being named after the market 'Bordeaux.' South of the Garonne extends the level barren moor of the Landes, reaching as far as the foot-hills of the Pyrenees. This region is, in summer, a baked steppe; in winter, an almost endless morass. Steps are now being taken to reclaim the soil by drainage and by planting forests of cork oak. The chances are good that it will soon be converted into a habitable country.

From the northern slopes of the Central Highlands flow the waters which form the Loire River. This river flows first north, and then westward, through a long, narrow fertile valley, emptying into the Atlantic south of the peninsula of Brittany. Its course, at Orleans, lies through the grain fields of France. At Angers are extensive nurseries and market gardens, while hemp-growing and manufacture are prominent. On the lower course of the Loire is the port of Nantes, the traditional receiving station for such groceries as are called 'colonial wares' on the Continent.

Preeminent among the rivers of France is the Seine, which gathers the streams of the gently sloping northern plains of France and flows with even tide into the English Channel. Early in its course it passes the centers of manufacture, and is cut up to afford water power. From Paris to Havre the banks are so closely built up that the Seine has been called a river-street. The largest river basin of France is that of the Loire; the most diversified that of the Rhône. The most fertile is the Garonne Valley, and the most densely populated the Valley of the Seine. The Seine has those qualities in a river which render it useful to man. As Michelet says: "It has not the capricious, perfidious softness of the Loire, nor the rough ways of the Garonne, nor

the terrible impetuosity of the Rhône, which comes down like a bull escaped from the Alps, traverses a lake fifty miles long, and rushes to the sea, biting at its shores as it goes."

Having thus reviewed some of the characteristics of the chief regions of France, let us consider the distribution of the population, and the location and character of the chief industries, agricultural, manufacturing and commercial, which are carried on by the French people. The population of France amounts to thirty-eight and one-half million souls. The rate of increase has been, for a number of years, less than that of surrounding nations. Because of this fact it may be observed that foreign nationalities are encroaching upon French territory from various sides. The Spaniards are flowing in around the eastern and western ends of the Pyrenees. The Italians invade Provence, and the Belgians and Germans the northeastern portion of the country, while there are large colonies of foreigners in Paris itself. Within the last forty years the internal movements of the population show that the valleys have gained at the expense of the mountains. The north has increased more rapidly than the south. The coal regions have amassed dense populations. The city portion of the population has risen from 24.42 per cent. in 1846 to 35.95 per cent. in 1886. Aggregate figures show that in that time the city population has been increased by five millions, while the country population has decreased two millions. The occupational statistics still show, however, that France is to be classed as preeminently an agricultural nation. Agriculture and industry are, however, not increasing as rapidly as commerce.

The peasantry of France are the foundation strata of the industrial pyramid upon which the superstructure of manufactures and commerce rests. They are a frugal and industrious class. Holdings of land are small in the fertile valleys, larger in the pasture country and communal in the mountains, where the land remains in a state of nature and where the shepherd must needs range widely with his flocks. The higher portions of the Pyrenees, Alps and Central Highlands are the sheep walks of France. Between these and the valleys stretches the belt of heavy pastures devoted to cattle-raising. As in England one hears of Scotch and Welsh cattle, so in France one hears of the cattle of Auvergne and Brittany. The stock are grown to full size in the pastures, and are then (such at least as are designed for Paris) shipped to the fertile plains around Paris, to be stall-fed and fattened. In like manner, the cattle sent to London from the north of England are 'finished,' to use the trade phrase, in a semicircle of country to the north of that city. The dairy industry must be sharply distinguished from cattle-raising. The economic problems presented by the two are quite different. In France

the dairy industry flourishes, especially in the low-lying, moist plains which border the English Channel. France has been divided into four agricultural regions. The first is the land of the olive, bordering the Mediterranean; the second, to the north of the other, is the corn belt, extending in the west to the island of Oléron; in the east, to the middle of the Vosges Mountains. The third is the vine country, limited on the north by a line drawn from the mouth of the Loire to the middle of the Ardennes. The vine is grown throughout central and southern France in detached areas, wherever the soil and exposure especially favor it. The northern plains compose the fourth agricultural region. They are devoted to grain, flax, potatoes, apples, small fruits and garden produce. Southwest of Paris lies the fertile plain of Beauce, the 'Granary of France,' described by Zola in 'La Terre,' and pictured by Millet. Agricultural methods are in the main clumsy and imperfect, and their defects are made up only by grinding toil. This condition of things has been explained as due to the conservatism of the peasant. There is an absence of newspapers and farmers' organizations to spread scientific knowledge concerning the processes of agriculture. The prevalence of small holdings prevents the profitable use of expensive agricultural machinery on private account. While the price of land is high, foreign competition keeps the price of staple products low.

As to mineral resources, France is generally accounted under, rather than over, supplied. There is everywhere an abundance of building-stone. Paris has exhaustless supplies within the municipal area. This has had not a little to do with the splendor and durability of Parisian architecture, which contrasts favorably with the brick of London and the stucco of Berlin. In the northwestern portion of the Central Highlands the mountains of Limonsin afford unexcelled porcelain clays, from which the famous Limoges china is made. The Jura Mountains produce mill-stones and lithographic stones. Brittany has a little tin. The Pyrenees offer nothing but mineral waters, except some iron in the extreme east. At Baccarat, in the Vosges, the ingredients for glass are found, and St. Gobain and St. Quirin manufacture plate glass. Nevertheless, France has perhaps less mineral wealth than any other well-known country of like extent. The chief defect is in connection with the supplies of iron and coal. Iron ore must always be transported to coal, for in producing iron two tons of coal are required to one ton of ore. It is to be desired, therefore, that coal should exist in large beds, accessible to the miner, and of proper quality for coking. Iron, though it may be in small deposits, should be free from certain impurities and not far distant from fuel and flux. France has no large beds of fine coal, and her iron ore is not of high grade; neither is it advantageously located with reference to coal. The largest collieries are in the extreme northeast, and extend across the border into Belgium.

Other important beds are southwest of Lyons at St. Etienne, and northwest of Lyons near Creuzot. Some anthracite is found in the Alps; some lignite near Marseilles.

The manufactures of France depend more largely upon skill and artistic ability, and less upon cheap coal and raw materials, than do those of England or Germany. The use of the 'factory system' secures the advantage of cheap motive power and the economy of machines, but it does not so much further the utilization of skill. This accounts, in part, for the persistence of household industries in France. The distribution of industrial skill depends upon the location of trade centers, where the traditions of craft have been handed down from generation to generation of workers. Here and there one finds an industry that grew up under royal patronage, often carried on for a time, as an exotic by Italian workmen, as was the case with the silk manufactures of Lyons. The industries of many towns are the survivals of those founded when the place was one of the privileged cities in which the Protestants were allowed to live and carry on trade. In other places industries are still carried on where they were attracted by mediæval church fairs, or royal courts, or by water powers no longer utilized, or harbors now silted up. Skill is a relatively immobile economic factor. The supplies of raw silk are either imported at or grown close to Marseilles, but to be manufactured they must be taken as far north as Lyons to secure a healthy and temperate climate. The manufacture of woolens is located at five points in France, each being midway between sheep-raising highlands and the populated valleys where markets are found. The supplies of raw cotton come chiefly from America, and are landed at Le Havre. Cotton manufacturing requires exactly such a moist climate as there prevails. It is, therefore, carried on in the lower valley of the Seine, or, at most, is removed but a short distance to the east to secure coal and a labor market. The linen manufactories are naturally in a flax-growing country, and center at Amiens and Lille. The Liverpool of France is Le Havre. Its Birmingham is St. Etienne. The French Manchester is said to be Montluçon. The bank center and city of diversified industries, corresponding to London, is Paris. There a vast variety of art goods, conveniences and luxuries, such as Gobelin's tapestry and *articles de vertu*, collectively known to the trade as 'Articles of Paris,' are manufactured.

The commercial routes of France have been remarkably distinct from the earliest historical times. The railways of France have opened fewer new arteries of trade, and have destroyed less of the old equilibrium of industry than it has been their fate to do in most other countries. The distribution of large cities serves well to show where these commercial highways are located. The southern trade moves from Marseilles to the Rhône Valley, and across the plains to Paris, or it

passes to the west down the Garonne Valley to Bordeaux From Bordeaux a route passes northward, to the west of the highlands, and along the coast to the city of Tours. At Tours this stream of trade is joined by that from the southern and western seas, and is carried inland to Paris. The great capital receives these streams from the south and feeds, and is in turn fed, from the fan-shaped network of commercial highways which branch out in every direction over the plains of the north. The chief of these bring Paris into close communication with Belgium and the coast.

Paris is situated in the center of the largest habitable plain of France. It is at the place where the road from the Mediterranean crosses the overland route from Spain to the low countries. The capital is near enough to the most important disputed boundaries to be able to throw the power of the nation into their protection, yet it is far enough inland from the channel to be safe from naval attack. The latitude gives Paris a climate which permits of continuous labor, and does not unduly complicate municipal sanitary problems. The metropolis is surrounded by regions which supplement one another in a beautiful manner in ministering to her necessities. On the northeast is a group of large cities devoted to the textile industries. In the southeast are the chalk plains, famous for wine. From the southwest comes grain. Due west are the Percheron and Norman hills furnishing their celebrated breeds of horses, while from further away, Brittany sends butter and eggs, honey and fish. Along the shores in the north and west are the ports of Dunkerque, Calais, Dieppe and Le Havre, for communication, while the lover of surf bathing finds the beach of Trouville not far away. The immediate environs have had not a little to do with the prosperity of the city. The merits of these are abundant artesian water and fine building-stone, a fertile surrounding soil able to assist in provisioning a metropolis, and romantic beauty of landscape, able, in the days of a monarchy, to attract a king to erect palaces and, in those of a republic, to stimulate a matter-of-fact *bourgeois*, and refresh an exhausted *ouvrier* on a holiday outing.

PEARSON'S GRAMMAR OF SCIENCE.

ANNOTATIONS ON THE FIRST THREE CHAPTERS.

By C. S. PEIRCE.

IF any follower of Dr. Pearson thinks that in the observations I am about to make I am not sufficiently respectful to his master, I can assure him that without a high opinion of his powers I should not have taken the trouble to make these annotations, and without a higher opinion still, I should not have used the bluntness which becomes the impersonal discussions of mathematicians.

An introductory chapter of ethical content sounds the dominant note of the book. The author opens with the declaration that our conduct ought to be regulated by the Darwinian theory. Since that theory is an attempt to show how natural causes tend to impart to stocks of animals and plants characters which, in the long run, promote reproduction and thus insure the continuance of those stocks, it would seem that making Darwinism the guide of conduct ought to mean that the continuance of the race is to be taken as the *summum bonum*, and '*Multiplicamini*' as the epitome of the moral law. Professor Pearson, however, understands the matter a little differently, expressing himself thus: "The sole reason [for encouraging] any form of human activity . . . lies in this: [its] existence tends to promote the welfare of human society, to increase social happiness, or to strengthen social stability. In the spirit of the age we are bound to question the value of science; to ask in what way it increases the happiness of mankind or promotes social efficiency."

The second of these two statements omits the phrase, 'the welfare of human society,' which conveys no definite meaning; and we may, therefore, regard it as a mere diluent, adding nothing to the essence of what is laid down. Strict adhesion to Darwinian principles would preclude the admission of the 'happiness of mankind' as an ultimate aim. For on those principles everything is directed to the continuance of the stock, and the individual is utterly of no account, except in so far as he is an agent of reproduction. Now there is no other happiness of mankind than the happiness of individual men. We must, therefore, regard this clause as logically deleterious to the purity of the doctrine. As to 'social stability,' we all know very well what ideas this phrase is intended to convey to English apprehensions; and it must be admitted that Darwinism, generalized in due measure, may apply to English

society the same principles that Darwin applied to breeds. A family in which the standards of that society are not traditional will go under and die out, and thus 'social stability' tends to be maintained.

But against the doctrine that social stability is the sole justification of scientific research, whether this doctrine be adulterated or not with the utilitarian clause, I have to object, first, that it is historically false, in that it does not accord with the predominant sentiment of scientific men; second, that it is bad ethics; and, third, that its propagation would retard the progress of science.

Professor Pearson does not, indeed, pretend that that which effectually animates the labors of scientific men is any desire 'to strengthen social stability.' Such a proposition would be too grotesque. Yet if it was his business, in treating of the grammar of science, to set forth the legitimate motive to research—as he has deemed it to be—it was certainly also his business, especially in view of the splendid successes of science, to show what has, in fact, moved such men. They have, at all events, not been inspired by a wish either to 'support social stability' or, in the main, to increase the sum of men's pleasures. The man of science has received a deep impression of the majesty of truth, as that to which, sooner or later, every knee must bow. He has further found that his own mind is sufficiently akin to that truth, to enable him, on condition of submissive observation, to interpret it in some measure. As he gradually becomes better and better acquainted with the character of cosmical truth, and learns that human reason is its issue and can be brought step by step into accord with it, he conceives a passion for its fuller revelation. He is keenly aware of his own ignorance, and knows that personally he can make but small steps in discovery. Yet, small as they are, he deems them precious; and he hopes that by conscientiously pursuing the methods of science he may erect a foundation upon which his successors may climb higher. This, for him, is what makes life worth living and what makes the human race worth perpetuation. The very being of law, general truth, reason—call it what you will—consists in its expressing itself in a cosmos and in intellects which reflect it, and in doing this progressively; and that which makes progressive creation worth doing—so the researcher comes to feel—is precisely the reason, the law, the general truth for the sake of which it takes place.

Such, I believe, as a matter of fact, is the motive which effectually works in the man of science. That granted, we have next to inquire which motive is the more rational, the one just described or that which Professor Pearson recommends. The ethical text-books offer us classifications of human motives. But for our present purpose it will suffice to pass in rapid review some of the more prominent ethical classes of motives.

A man may act with reference only to the momentary occasion, either from unrestrained desire, or from preference for one desideratum over another, or from provision against future desires, or from persuasion, or from imitative instinct, or from dread of blame, or in awed obedience to an instant command; or he may act according to some general rule restricted to his own wishes, such as the pursuit of pleasure, or self-preservation, or good-will toward an acquaintance, or attachment to home and surroundings, or conformity to the customs of his tribe, or reverence for a law; or, becoming a moralist, he may aim at bringing about an ideal state of things definitely conceived, such as one in which everybody attends exclusively to his own business and interest (individualism), or in which the maximum total pleasure of all beings capable of pleasure is attained (utilitarianism), or in which altruistic sentiments universally prevail (altruism), or in which his community is placed out of all danger (patriotism), or in which the ways of nature are as little modified as possible (naturalism); or he may aim at hastening some result not otherwise known in advance than as that, whatever it may turn out to be, to which some process seeming to him good must inevitably lead, such as whatever the dictates of the human heart may approve (sentimentalism), or whatever would result from every man's duly weighing, before action, the advantages of his every purpose (to which I will attach the nonce-name *entelism*, distinguishing it and others below by italics), or whatever the historical evolution of public sentiment may decree (*historicism*), or whatever the operation of cosmical causes may be destined to bring about (evolutionism); or he may be devoted to truth, and may be determined to do nothing not pronounced reasonable, either by his own cogitations (rationalism), or by public discussion (dialecticism), or by crucial experiment; or he may feel that the only thing really worth striving for is the generalizing or assimilating elements in truth, and that either as the sole object in which the mind can ultimately recognize its veritable aim (educationalism), or that which alone is destined to gain universal sway (pancratism); or, finally, he may be filled with the idea that the only reason that can reasonably be admitted as ultimate is that living reason for the sake of which the psychical and physical universe is in process of creation (*religionism*).

This list of ethical classes of motives may, it is hoped, serve as a tolerable sample upon which to base reflections upon the acceptability as ultimate of different kinds of human motives; and it makes no pretension to any higher value. The enumeration has been so ordered as to bring into view the various degrees of generality of motives. It would conduce to our purpose, however, to compare them in other respects. Thus, we might arrange them in reference to the degree to which an impulse of dependence enters into them, from express obedi-

ence, generalized obedience, conformity to an external exemplar, action for the sake of an object regarded as external, the adoption of a motive centering on something which is partially opposed to what is present, the balancing of one consideration against another, until we reach such motives as unrestrained desire, the pursuit of pleasure, individualism, sentimentalism, rationalism, educationalism, religionism, in which the element of otherness is reduced to a minimum. Again, we might arrange the classes of motives according to the degree in which immediate qualities of feeling appear in them, from unrestrained desire, through desire present but restrained, action for self, action for pleasure generalized beyond self, motives involving a retro-consciousness of self in outward things, the personification of the community, to such motives as direct obedience, reverence, naturalism, evolutionism, experimentalism, pancratism, religionism, in which the element of self-feeling is reduced to a minimum. But the important thing is to make ourselves thoroughly acquainted, as far as possible from the inside, with a variety of human motives ranging over the whole field of ethics.

I will not go further into ethics than simply to remark that all motives that are directed toward pleasure or self-satisfaction, of however high a type, will be pronounced by every experienced person to be inevitably destined to miss the satisfaction at which they aim. This is true even of the highest of such motives, that which Josiah Royce develops in his 'World and Individual.' On the other hand, every motive involving dependence on some other leads us to ask for some ulterior reason. The only desirable object which is quite satisfactory in itself without any ulterior reason for desiring it, is the reasonable itself. I do not mean to put this forward as a demonstration; because, like all demonstrations about such matters, it would be a mere quibble, a sheaf of fallacies. I maintain simply that it is an experiential truth.

The only ethically sound motive is the most general one; and the motive that actually inspires the man of science, if not quite that, is very near to it—nearer, I venture to believe, than that of any other equally common type of humanity. On the other hand, Professor Pearson's aim, 'the stability of society,' which is nothing but a narrow British patriotism, prompts the *cui bono* at once. I am willing to grant that England has been for two or three centuries a most precious factor of human development. But there were and are *reasons* for this. To demand that man should aim at the stability of British society, or of society at large, or the perpetuation of the race, as an *ultimate* end, is too much. The human species will be extirpated sometime; and when the time comes the universe will, no doubt, be well rid of it. Professor Pearson's ethics are not at all improved by being adulterated with utilitarianism, which is a lower motive still. Utilitarianism is one of

the few theoretical motives which has unquestionably had an extremely beneficial influence. But the greatest happiness of the greatest number, as expounded by Bentham, resolves itself into merely superinducing the quality of pleasure upon men's immediate feelings. Now, if the pursuit of pleasure is not a satisfactory ultimate motive for me, why should I enslave myself to procuring it for others? Leslie Stephen's book was far from uttering the last word upon ethics; but it is difficult to comprehend how anybody who has read it reflectively can continue to hold the mixed doctrine that no action is to be encouraged for any other reason than that it either tends to the stability of society or to general happiness.

Ethics, as such, is extraneous to a Grammar of Science; but it is a serious fault in such a book to inculcate reasons for scientific research the acceptance of which must tend to lower the character of such research. Science is, upon the whole, at present in a very healthy condition. It would not remain so if the motives of scientific men were lowered. The worst feature of the present state of things is that the great majority of the members of many scientific societies, and a large part of others, are men whose chief interest in science is as a means of gaining money, and who have a contempt, or half-contempt, for pure science. Now, to declare that the sole reason for scientific research is the good of society is to encourage those pseudo-scientists to claim, and the general public to admit, that they, who deal with the applications of knowledge, are the true men of science, and that the theoreticians are little better than idlers.

In Chapter II., entitled 'The Facts of Science,' we find that the 'stability of society' is not only to regulate our conduct, but, also, that our opinions have to be squared to it. In section 10 we are told that we must not believe a certain purely theoretical proposition because it is 'anti-social' to do so, and because to do so 'is opposed to the interests of society.' As to the 'canons of legitimate inference' themselves, that are laid down by Professor Pearson, I have no great objection to them. They certainly involve important truths. They are excessively vague and capable of being twisted to support illogical opinions, as they are twisted by their author, and they leave much ground uncovered. But I will not pursue these objections. I do say, however, that truth is truth, whether it is opposed to the interests of society to admit it or not—and that the notion that we must deny what it is not conducive to the stability of British society to affirm is the mainspring of the mendacity and hypocrisy which Englishmen so commonly regard as virtues. I must confess that I belong to that class of scallawags who purpose, with God's help, to look the truth in the face, whether doing so be conducive to the interests of society or not. Moreover, if I should ever attack that excessively difficult problem, 'What is for the true interest of society?' I

should feel that I stood in need of a great deal of help from the science of legitimate inference; and, therefore, to avoid running round a circle, I will endeavor to base my theory of legitimate inference upon something less questionable—as well as more germane to the subject—than the true interest of society.

The remainder of this chapter on the 'Facts of Science' is taken up with a theory of cognition, in which the author falls into the too common error of confounding psychology with logic. He will have it that knowledge is built up out of sense-impressions—a correct enough statement of a conclusion of psychology. Understood, however, as Professor Pearson understands and applies it, as a statement of the nature of our logical data, of 'the facts of science,' it is altogether incorrect. He tells us that each of us is like the operator at a central telephone office, shut out from the external world, of which he is informed only by sense-impressions. Not at all! Few things are more completely hidden from my observation than those hypothetical elements of thought which the psychologist finds reason to pronounce 'immediate,' in his sense. But the starting point of all our reasoning is not in those sense-impressions, but in our percepts. When we first wake up to the fact that we are thinking beings and can exercise some control over our reasonings, we have to set out upon our intellectual travels from the home where we already find ourselves. Now, this home is the parish of percepts. It is not inside our skulls, either, but out in the open. It is the external world that we directly observe. What passes within we only know as it is mirrored in external objects. In a certain sense, there is such a thing as introspection; but it consists in an interpretation of phenomena presenting themselves as external percepts. We first see blue and red things. It is quite a discovery when we find the eye has anything to do with them, and a discovery still more recondite when we learn that there is an *ego* behind the eye, to which these qualities properly belong. Our logically initial data are percepts. Those percepts are undoubtedly purely psychical, altogether of the nature of thought. They involve three kinds of psychical elements, their qualities of feelings, their reaction against my will, and their generalizing or associating element. But all that we find out afterward. I see an inkstand on the table: that is a percept. Moving my head, I get a different percept of the inkstand. It coalesces with the other. What I call the inkstand is a generalized percept, a quasi-inference from percepts, perhaps I might say a composite-photograph of percepts. In this psychical product is involved an element of resistance to me, which I am obscurely conscious of from the first. Subsequently, when I accept the hypothesis of an inward subject for my thoughts, I yield to that consciousness of resistance and admit the inkstand to the standing of an external object. Still later, I may call this in question. But

as soon as I do that, I find that the inkstand appears there in spite of me. If I turn away my eyes, other witnesses will tell me that it still remains. If we all leave the room and dismiss the matter from our thoughts, still a photographic camera would show the inkstand still there, with the same roundness, polish and transparency, and with the same opaque liquid within. Thus, or otherwise, I confirm myself in the opinion that its characters are what they are, and persist at every opportunity in revealing themselves, regardless of what you, or I, or any man, or generation of men, may think that they are. That conclusion to which I find myself driven, struggle against it as I may, I briefly express by saying that the inkstand is a *real* thing. Of course, in being real and external, it does not in the least cease to be a purely psychical product, a generalized percept, like everything of which I can take any sort of cognizance.

It might not be a very serious error to say that the facts of science are sense-impressions, did it not lead to dire confusion upon other points. We see this in Chapter III., in whose long meanderings through irrelevant subjects, in the endeavor to make out that there is no rational element in nature, and that the rational element of natural laws is imported into them by the minds of their discoverers, it would be impossible for the author to lose sight entirely of the bearing of the question which he himself has distinctly formulated, if he were not laboring with the confusing effects of his notion that the data of science are the sense-impressions. It does not occur to him that he is laboring to prove that the mind has a marvelous power of creating an element absolutely supernatural—a power that would go far toward establishing a dualism quite antagonistic to the spirit of his philosophy. He evidently imagines that those who believe in the reality of law, or the rational element in nature, fail to apprehend that the data of science are of a psychical nature. He even devotes a section to proving that natural law does not belong to things-in-themselves, as if it were possible to find any philosopher who ever thought it did. Certainly, Kant, who first decked out philosophy with these chaste ornaments of things-in-themselves, was not of that opinion; nor could anybody well hold it after what he wrote. In point of fact, it is not Professor Pearson's opponents but he himself who has not thoroughly assimilated the truth that everything we can in any way take cognizance of is purely mental. This is betrayed in many little ways, as, for instance, when he makes his answer to the question, whether the law of gravitation ruled the motion of the planets before Newton was born, to turn upon the circumstance that the law of gravitation is a formula expressive of the motion of the planets 'in terms of a purely mental conception,' as if there could be a conception of anything not purely mental. Repeatedly, when he has proved the content of an idea to be mental, he seems to

think he has proved its object to be of human origin. He goes to no end of trouble to prove in various ways, what his opponent would have granted with the utmost cheerfulness at the outset, that laws of nature are rational; and, having got so far, he seems to think nothing more is requisite than to seize a logical maxim as a leaping pole and lightly skip to the conclusion that the laws of nature are of human provenance. If he had thoroughly accepted the truth that all realities, as well as all figments, are alike of purely mental composition, he would have seen that the question was, not whether natural law is of an intellectual nature or not, but whether it is of the number of those intellectual objects that are destined ultimately to be exploded from the spectacle of our universe, or whether, as far as we can judge, it has the stuff to stand its ground in spite of all attacks. In other words, is there anything that is really and truly a law of nature, or are all pretended laws of nature figments, in which latter case, all natural science is a delusion, and the writing of a grammar of science a very idle pastime?

Professor Pearson's theory of natural law is characterized by a singular vagueness and by a defect so glaring as to remind one of the second book of the *Novum Organum* or of some strong chess-player whose attention has been so riveted upon a part of the board that a fatal danger has, as it were, been held upon the blind-spot of his mental retina. The manner in which the current of thought passes from the woods into the open plain and back again into the woods, over and over again, betrays the amount of labor that has been expended upon the chapter. The author calls attention to the sifting action both of our perceptive and of our reflective faculties. I think that I myself extracted from that vein of thought pretty much all that is valuable in reference to the regularity of nature in the POPULAR SCIENCE MONTHLY for June, 1878, (p. 208). I there remarked that the degree to which nature seems to present a general regularity depends upon the fact that the regularities in it are of interest and importance to us, while the irregularities are without practical use or significance; and in the same article I endeavored to show that it is impossible to conceive of nature's being markedly less regular, taking it, 'by and large,' than it actually is. But I am confident, from having repeatedly returned to that line of thought that it is impossible legitimately to deduce from any such considerations the unreality of natural law. 'As a pure suggestion and nothing more,' toward the end of the chapter, after his whole plea has been put in, Dr. Pearson brings forward the idea that a transcendental operation of the perceptive faculty may reject a mass of sensation altogether and arrange the rest in place and time, and that to this the laws in nature may be attributable—a notion to which Kant undoubtedly leaned at one time. The mere emission of such a theory, after his argument has been fully set forth, almost amounts to a confession of failure to

prove his proposition. Granting, by way of waiver, that such a theory is intelligible and is more than a nonsensical juxtaposition of terms, so far from helping Professor Pearson's contention at all, the acceptance of it would at once decide the case against him, as every student of the *Critic of the Pure Reason* will at once perceive. For the theory sets the rationality in nature upon a rock perfectly impregnable by you, me or any company of men.

Although that theory is only problematically put forth by Professor Pearson, yet at the very outset of his argumentation he insists upon the relativity of regularity to our faculties, as if that were in some way pertinent to the question. "Our law of tides," he says, "could have no meaning for a blind worm on the shore, for whom the moon had no existence." Quite so; but would that truism in any manner help to prove that the moon was a figment and no reality? On the contrary, it could only help to show that there may be more things in heaven and earth than your philosophy has dreamed of. Now the *moon*, on the one hand, and the *law of the tides*, on the other, stand in entirely analogous positions relatively to the remark, which can no more help to prove the unreality of the one than of the other. So, too, the final decisive stroke of the whole argumentation consists in urging substantially the same idea in the terrible shape of a syllogism, which the reader may examine in section 11. I will make no comment upon it.

Professor Pearson's argumentation rests upon three legs. The first is the fact that both our perceptive and our reflective faculties reject part of what is presented to them, and 'sort out' the rest. Upon that, I remark that our minds are not, and cannot be, positively mendacious. To suppose them so is to misunderstand what we all mean by truth and reality. Our eyes tell us that some things in nature are red and others blue; and so they really are. For the real world is the world of insistent generalized percepts. It is true that the best physical idea which we can at present fit to the real world, has nothing but longer and shorter waves to correspond to red and blue. But this is evidently owing to the acknowledged circumstance that the physical theory is to the last degree incomplete, if not to its being, no doubt, in some measure, erroneous. For surely the completed theory will have to account for the extraordinary contrast between red and blue. In a word, it is the business of a physical theory to account for the percepts; and it would be absurd to accuse the percepts—that is to say, the facts—of mendacity because they do not square with the theory.

The second leg of the argumentation is that the mind projects its worked-over impressions into an object, and then projects into that object the comparisons, etc., that are the results of its own work. I admit, of course, that errors and delusions are everyday phenomena, and hallucinations not rare. We have just three means at our command for

detecting any unreality, that is, lack of insistency, in a notion. First, many ideas yield at once to a direct effort of the will. We call them *fancies*. Secondly, we can call in other witnesses, including ourselves under new conditions. Sometimes dialectic disputation will dispel an error. At any rate, it may be voted down so overwhelmingly as to convince even the person whom it affects. Thirdly, the last resort is prediction and experimentation. Note that these two are equally essential parts of this method, which Professor Pearson keeps—I had almost said sedulously—out of sight in his discussion of the rationality of nature. He only alludes to it when he comes to his transcendental 'pure suggestion.' Nothing is more notorious than that this method of prediction and experimentation has proved the master-key to science; and yet, in Chapter IV., Professor Pearson tries to persuade us that prediction is no part of science, which must only describe sense-impressions. [A sense-impression cannot be described.] He does not say that he would permit generalization of the facts. He ought not to do so, since generalization inevitably involves prediction.

The third leg of the argumentation is that human beings are so much alike that what one man perceives and infers another man will be likely to perceive and infer. This is a recognized weakness of the second of the above methods. It is by no means sufficient to destroy that method, but along with other defects it does render resort to the third method imperative. When I see Dr. Pearson passing over without notice the first and third of the only three possible ways of distinguishing whether the rationality of nature is real or not, and giving a lame excuse for reversing the verdict of the second, so that his decision seems to spring from antecedent predilection, I cannot recommend his procedure as affording such an exemplar of the logic of science as one might expect to find in a grammar of science.

An ignorant sailor on a desert island lights in some way upon the idea of the parallelogram of forces, and sets to work making experiments to see whether the actions of bodies conform to that formula. He finds that they do so, as nearly as he can observe, in many trials invariably. He wonders why inanimate things should thus conform to a widely general intellectual formula. Just then, a disciple of Professor Pearson lands on the island and the sailor asks him what he thinks about it. "It is very simple," says the disciple, "you see you made the formula and then you projected it into the phenomena." *Sailor:* What are the phenomena? *Pearsonist:* The motions of the stones you experimented with. *Sailor:* But I could not tell until afterward whether the stones had acted according to the rule or not. *Pearsonist:* That makes no difference. You made the rule by looking at some stones, and all stones are alike. *Sailor:* But those I used were very unlike, and I want to know what made them all move exactly according to one rule. *Pear-*

sonist: Well, maybe your mind is not in time, and so you made all the things behave the same way at all times. Mind, I don't say it is so; but it may be. *Sailor:* Is that all you know about it? Why not say the stones are made to move as they do by something *like* my mind?

When the disciple gets home, he consults Dr. Pearson. "Why," says Dr. Pearson, "you must not deny that the facts are really concatenated; only there is no rationality about that." "Dear me," says the disciple, "then there really is a concatenation that makes all the component accelerations of all the bodies scattered through space conform to the formula that Newton, or Lami, or Varignon invented?" "Well, the formula is the device of one of those men, and it conforms to the facts." "To the facts its inventor knew, and also to those he only predicted?" "As for prediction, it is unscientific business." "Still the prediction and the facts predicted agree." "Yes." "Then," says the disciple, "it appears to me that there really is in nature something extremely like action in conformity with a highly general intellectual principle." "Perhaps so," I suppose Dr. Pearson would say, "but nothing in the least like rationality." "Oh," says the disciple, "I thought rationality was conformity to a widely general principle."

CHAPTERS ON THE STARS.

By Professor SIMON NEWCOMB, U. S. N.

THE STRUCTURE OF THE HEAVENS.

THE problem of the structure and duration of the universe is the most far-reaching with which the mind has to deal. Its solution may be regarded as the ultimate object of stellar astronomy, the possibility of reaching which has occupied the minds of thinkers since the beginning of civilization. Before our time the problem could be considered only from the imaginative or the speculative point of view. Although we can to-day attack it by scientific methods, to a limited extent, it must be admitted that we have scarcely taken more than the first step toward the actual solution. We can do little more than state the questions involved, and show what light, if any, science is able to throw upon the possible answers.

Firstly, we may inquire as to the extent of the universe of stars. Are the latter scattered through infinite space, so that those we see are merely that portion of an infinite collection which happens to be within reach of our telescopes, or are all the stars contained within a certain limited space? In the latter case, have our telescopes yet penetrated to the boundary in any direction? In other words, as, by the aid of increasing telescopic power, we see fainter and fainter stars, are these fainter stars at greater distances than those before known, or are they smaller stars contained within the same limits as those we already know? Otherwise stated, do we see stars on the boundary of the universe?

Secondly, granting the universe to be finite, what is the arrangement of the stars in space? Especially, what is the relation of the galaxy to the other stars? In what sense, if any, can the stars be said to form a permanent system? Do the stars which form the Milky Way belong to a different system from the other stars, or are the latter a part of one universal system?

Thirdly, what is the duration of the universe in time? Is it fitted to last forever in its present form, or does it contain within itself the seeds of dissolution? Must it, in the course of time, in we know not how many millions of ages, be transformed into something very different from what it now is? This question is intimately associated with the question whether the stars form a system. If they do, we may suppose that system to be permanent in its general features; if not, we must look further for our conclusion.

The first and third of these questions will be recognized by students of Kant as substantially those raised by the great philosopher in the form of antinomies. Kant attempted to show that both the propositions and their opposites could be proved or disproved by reasoning equally valid in either case. The doctrine that the universe is infinite in duration and that it is finite in duration are both, according to him, equally susceptible of disproof. To his reasoning on both points the scientific philosopher of to-day will object that it seeks to prove or disprove, *à priori*, propositions which are matters of fact, of which the truth can be therefore settled only by an appeal to observation. The more correct view is that afterward set forth by Sir William Hamilton, that it is equally impossible for us to conceive of infinite space (or time), or of space (or time) coming to an end. But this inability merely grows out of the limitations of our mental power, and gives us no clue to the actual universe. So far as the questions are concerned with the latter, no answer is valid unless based on careful observation. Our reasoning must have facts to go upon before a valid conclusion can be reached.

The first question we have to attack is that of the extent of the universe. In its immediate and practical form, it is whether the smallest stars that we see are at the boundary of a system, or whether more and more lie beyond, to an infinite extent. This question we are not yet ready to answer with any approach to certainty. Indeed, from the very nature of the case, the answer must remain somewhat indefinite. If the collection of stars which forms the Milky Way be really finite, we may not yet be able to see its limit. If we do see its limit, there may yet be, for aught we know, other systems and other galaxies, scattered through infinite space, which must forever elude our powers of vision. Quite likely the boundary of the system may be somewhat indefinite, the stars gradually thinning out as we go further and further, so that no definite limit can be assigned. If all stars are of the same average brightness as those we see, all that lie beyond a certain distance must evade observation, for the simple reason that they are too far off to be visible in our telescopes.

There is a law of optics which throws some light on the question. Suppose the stars to be scattered through infinite space in such a way that every great portion of space is, in the general average, about equally rich in stars.

Then imagine that, at some great distance, say that of the average stars of the sixth magnitude, we describe a sphere having its center in our system. Outside this sphere, describe another one, having a radius greater by a certain quantity, which we may call S. Outside that let there be another of a radius yet greater, and so on indefinitely. Thus we shall have an endless succession of concentric spherical shells, each of the same thickness, S. The volume of each of these regions will be

proportional to the square of the diameters of the spheres which bound it. Hence, supposing an equal distribution of the stars, each of these regions will contain a number of stars increasing as the square of the radius of the region. Since the amount of light which we receive from each individual star is as the inverse square of its distance, it follows that the sum total of the light received from each of these spherical shells will be equal. Thus, as we include sphere after sphere, we add equal amount of light without limit. The result of the successive addition of these equal quantities, increasing without limit, would be that if the system of stars extended out indefinitely the whole heavens would be filled with a blaze of light as bright as the sun.

Now, as a matter of fact, such is very far from being the case. It follows that infinite space is not occupied by the stars. At best there can only be collections of stars at great distances apart.

The nearest approximation to such an appearance as that described is the faint, diffused light of the Milky Way. But so large a fraction of this illumination comes from the stars which we actually see in the telescope that it is impossible to say whether any visible illumination results from masses of stars too faint to be individually seen. Whether the cloud-like impressions, which Barnard has found in long-exposed photographs of the Milky Way, are produced by countless distant stars, too faint to impress themselves even upon the most sensitive photographic plate, is a question of extreme interest which cannot be answered. But even if we should answer it in the affirmative, the extreme faintness of light shows that the stars which produce it are not scattered through infinite space; but that, although they may extend much beyond the limits of the visible stars, they thin out very rapidly. The evidence, therefore, seems to be against the hypothesis that the stars we see form part of an infinitely extended universe.

But there are two limitations to this conclusion. It rests upon the hypothesis that light is never lost in its passage to any distance, however great. This hypothesis is in accordance with our modern theories of physics, yet it cannot be regarded as an established fact for all space, even if true for the distances of the visible stars. About half a century ago Struve propounded the contrary hypothesis that the light of the more distant stars suffers an extinction in its passage to us. But this had no other basis than the hypothesis that the stars were equally thick out to the farthest limits at which we could see them.

It might be said that he assumed the hypothesis of an infinite universe, and from the fact that he did not see the evidence of infinity, concluded that light was lost. The hypothesis of a limited universe and no extinction of light, while not absolutely proved, must be regarded

as the one to be accepted until further investigation shall prove its unsoundness.

The second limitation has been the possible structure of an infinite universe. The mathematical reader will easily see that the conclusion that an infinite universe of stars would fill the heavens with a blaze of light, rests upon the hypothesis that every region of space of some great but finite extent is, on the average, occupied by at least one star. In other words, the hypothesis is that if we divide the total number of the stars by the number of cubic miles of space, we shall have a finite quotient. But an infinite universe can be imagined which does not fill this condition. Such will be the case with one constructed on the celebrated hypothesis of Lambert, propounded in the latter part of the last century. This author was an eminent mathematician, who seems to have been nearly unique in combining the mathematical and the speculative sides of astronomy. He assumed a universe constructed on an extension of the plan of the Solar System. The smallest system of bodies is composed of a planet with its satellites. We see a number of such systems, designated as the Terrestrial, the Martian (Mars and its satellites), the Jovian (Jupiter and its satellites), etc., all revolving round the Sun, and thus forming one greater system, the Solar System. Lambert extended the idea by supposing that a number of solar systems, each formed of a star with its revolving planets and satellites, were grouped into a yet greater system. A number of such groups form the great system which we call the galaxy, and which comprises all the stars we can see with the telescope. The more distant clusters may be other galaxies. All these systems again may revolve around some distant center, and so on to an indefinite extent. Such a universe, how far so ever it might extend, would fill the heavens with a blaze of light, and the more distant galaxies might remain forever invisible to us. But modern developments show that there is no scientific basis for this conception, attractive though it is by its grandeur.

So far as our present light goes, we must conclude that although we are unable to set absolute bounds to the universe, yet the great mass of stars is included within a limited space of whose extent we have as yet no evidence. Outside of this space there may be scattered stars or invisible systems. But if these systems exist, they are distinct from our own.

The second question, that of the arrangement of the stars in space, is one on which it is equally difficult to propound a definite general conclusion. So far, we have only a large mass of faint indications, based on researches which cannot be satisfactorily completed until great additions are made to our fund of knowledge.

A century ago Sir William Herschel reached the conclusion that our universe was composed of a comparatively thin but widely ex-

tended stratum of stars. To introduce a familiar object, its figure was that of a large thin grindstone, our Solar System being near the center. Considering only the general aspect of the heavens, this conclusion was plausible. Suppose a mass of a million of stars scattered through a space of this form. It is evident that an observer in the center, when he looks through the side of the stratum, would see few stars. The latter would become more and more numerous as he directed his vision toward the circumference of the stratum. In other words, assuming the universe to have this form, we should see a uniform, cloud-like arch spanning the heavens—a galaxy in fact.

This view of the figure of the universe was also adopted by Struve, who was, the writer believes, the first astronomer after Herschel to make investigations which can be regarded as constituting an important addition to thought on the subject. To a certain extent we may regard the hypothesis as incontestable. The great mass of the visible stars is undoubtedly contained within such a figure as is here supposed.

To show this let Fig. 1 represent a cross section of the heavens at

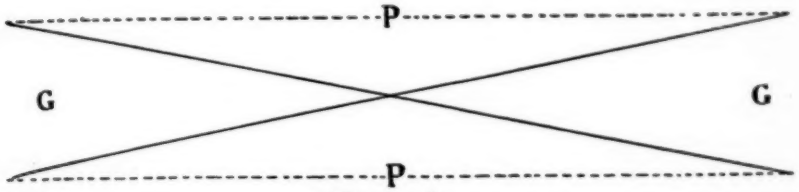

FIG. 1.

right angles to the Milky Way, the Solar System being at S. It is an observed fact that the stars are vastly more numerous in the galactic regions G G than in the regions P P. Hence, if we suppose the stars equally scattered, they must extend much farther out in G G than in P P. If they extend as far in the one direction as in the other, then they must be more crowded in the galactic belt. It will still remain true that the greater number of the stars are included in the flat region A B C D, those outside this stratum being comparatively few in number.*

But we cannot assume that this hypothesis of the form of the universe affords the basis for a satisfactory conception of its arrangement. Were it the whole truth, the stars would be uniformly dense along the whole length of the Milky Way. Now, it is a familiar fact that this is not the case. The Milky Way is not a uniformly illuminated belt, but a chain of irregular, cloud-like aggregations of stars. Starting from this fact as

* Regarding the galaxy as a belt spanning the heavens, the central line of which is a great circle, the poles of the galaxy are the two opposite points in the heavens everywhere 90° from this great circle. Their direction is that of the two ends of the axle of the grindstone, as seen by an observer in the center, while the galaxy would be the circumference of the stone.

a basis, our best course is to examine the most plausible hypotheses we can make as to the distribution of the stars which do not belong to the galaxy, and see which agrees best with observation.

Let Fig. 2 represent a section of the galactic ring or belt in its own plane, with the sun near the center S. To an observer at a vast distance in the direction of either pole of the galaxy, the latter would appear of this form. Let Fig. 3 represent a cross section as viewed by an observer in the plane of the galaxy at a great distance outside of it. How would the stars that do not belong to the galaxy be situated? We may make three hypotheses:

1. That they are situated in a sphere (A B) as large as the galaxy itself. Then the whole universe of stars would be spherical in outline, and the galaxy would be a dense belt of stars girdling the sphere.

2. The remaining stars may still be contained in a spherical space

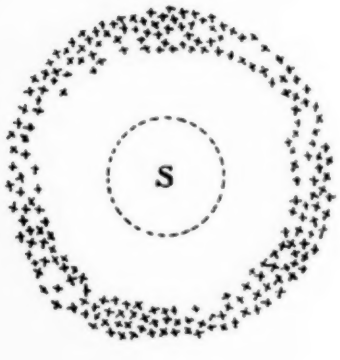

FIG. 2.

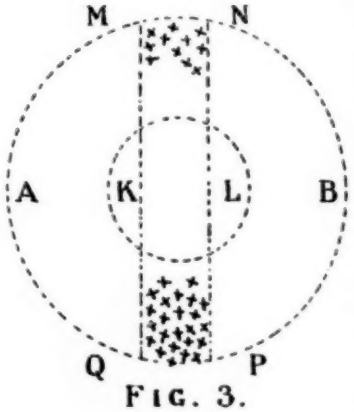

FIG. 3.

(K L), of which the diameter is much less than that of the galactic girdle. In this case our Sun would be one of a central agglomeration of stars, lying in or near the plane of the galaxy.

3. The non-galactic stars may be equally scattered throughout a flat region (M N P Q), of the grindstone form. This would correspond to the hypothesis of Herschel and Struve.

There is no likelihood that either of these hypotheses is true in all the geometric simplicity with which I have expressed them. Stars are doubtless scattered to some extent through the whole region M N P Q, and it is not likely that they are confined within limits defined by any geometrical figure. The most that can be done is to determine to which of the three figures the mutual arrangement most nearly corresponds.

The simplest test is that of the third hypothesis as compared with the other two. If the third hypothesis be true, then we should see the

fewest stars in the direction of the poles of the galaxy; and the number in any given portion of the celestial sphere, say one square degree, should continually increase, slowly at first, more rapidly afterwards, as we went from the poles toward the circumference of the galaxy. At a distance of 60° from the poles and 30° from the central line or circumference we should see more than twice as many stars per square degree as near the poles.

The general question of determining the precise position of the galaxy naturally enters into our problem. There is no difficulty in mapping out its general course by unaided eye observations of the heavens or a study of maps of the stars. Looking at the heavens, we shall readily see that it crosses the equator at two opposite points; the one east of the constellation Orion, between 6h. and 7h. of right ascension; the other at the opposite point, in Aquila, between 18h. and 19h. It makes a considerable angle with the equator, somewhat more than 60°. Consequently it passes within 30° of either pole. The point nearest of approach to the north pole is in the constellation Cassiopeia. In consequence of this obliquity to the equator, its apparent position on the celestial sphere, as seen in our latitude, goes through a daily change with the diurnal rotation of the earth. In the language of technical astronomy, every day at 12h. of sidereal time, it makes so small an angle with the horizon as to be scarcely visible. If the air is very clear, we might see a portion of it skirting the northern horizon. This position occurs during the evenings of early summer. At 0h. of sidereal time, which during autumn and early winter fall in the evening, it passes nearly through our zenith, from east to west, and can, therefore, then best be seen.

Its position can readily be determined by noting the general course of its brighter portions on a map of the stars, and then determining by inspection, or otherwise, the circle which will run most nearly through those portions. It is thus found that the position is nearly always near a great circle of the sphere. From the very nature of the case the position of this circle will be a little indefinite, and probably the estimates made of it have been based more on inspection than on computation. The following numerical positions have been assigned to the pole of the galaxy:

Gould, ...	R. A. = 12h. 41m.	Dec. = + 27° 21′
Herschel, W.....	12h. 29m.	31° 30′
Seeliger	12h. 49m.	27° 30′
Argelander	12h. 40m.	28° 5′

Were it possible to determine the distance of a star as readily as we do its direction, the problem of the distribution of the stars in space would be at once solved. This not being the case, we must first study the apparent arrangement of the stars with respect to the galaxy, with a

view of afterward drawing such conclusions as we can in regard to their distance.

APPARENT DISTRIBUTION OF THE STARS IN THE SKY.

Distribution of the Lucid Stars: Our question now is how are the stars, as we see them, distributed over the sky? We know in a general way that there are vastly more stars round the belt of the Milky Way than in the remainder of the heavens. But we wish to know in detail what the law of increase is from the poles of the galaxy to the belt itself.

In considering any question of the number of stars in a particular region of the heavens, we are met by a fundamental difficulty. We can set no limit to the minuteness of stars, and the number will depend upon the magnitude of those which we include in our account. As already remarked, there are, at least up to a certain limit, three or four times as many stars of each magnitude as of the magnitude next brighter. Now, the smallest stars that can be seen, or that may be included in any count, vary greatly with the power of the instrument used in making the count. If we had any one catalogue, extending over the whole celestial sphere, and made on an absolutely uniform plan, so that we knew it included all the stars down to some given magnitude, and no others, it would answer our immediate purpose. If, however, one catalogue should extend only to the ninth magnitude, while another should extend to the tenth, we should be led quite astray in assuming that the number of stars in the two catalogues expressed the star density in the regions which they covered. The one would show three or four times as many stars as the other, even though the actual density in the two cases were the same.

If we could be certain, in any one case, just what the limit of magnitude was for any catalogue, or if the magnitudes in different catalogues always corresponded to absolutely the same brightness of the star, this difficulty would be obviated. But this is the case only with that limited number of stars whose brightness has been photometrically measured. In all other cases our count must be more or less uncertain. One illustration of this will suffice:

I have already remarked that in making the photographic census of the southern heavens, Gill and Kapteyn did not assume that stars of which the images were equally intense on different plates were actually of the same magnitude. Each plate was assumed to have a scale of its own, which was fixed by comparing the intensity of the photographic impressions of those stars whose magnitudes had been previously determined with these determinations, and thus forming as it were a separate scale for each plate. But, in forming the catalogue from the international photographic chart of the heavens, it is assumed that the photographs taken with telescopes of the same aperture, in which

the plates are exposed for five minutes, will all correspond, and that the smallest stars found on the plates will be of the eleventh magnitude.

In the case of the lucid stars this difficulty does not arise, because the photometric estimates are on a sufficiently exact and uniform scale to enable us to make a count, which shall be nearly correct, of all the stars down to, say, magnitude 6.0 or some limit not differing greatly from this. Several studies of the distribution of these stars have been made; one by Gould in the *Uranometria Argentina*, one by Schiaparelli, and another by Pickering. The counts of Gould and Schiaparelli, having special reference to the Milky Way, are best adapted to our purpose. The most striking result of these studies is that the condensation in the Milky Way seems to commence with the brightest stars. A little consideration will show that we cannot, with any probability, look for such a condensation in the case of stars near to us. Whatever form we assign to the stellar universe, we shall expect the stars immediately around us to be equally distributed in every direction. Not until we approach the boundary of the universe in one direction, or some great masses like those of the galaxy in another direction, should we expect marked condensation round the galactic belt. Of course we might imagine that even the nearest stars are most numerous in the direction round the galactic circle. But this would imply an extremely unlikely arrangement, our system being as it were at the point of a cone. It is clear that if such were the case for one point, it could not be true if our Sun were placed anywhere except at this particular point. Such an arrangement of the stars round us is outside of all reasonable probability. Independent evidence of the equal distribution of the stars will hereafter be found in the proper motions. If then, the nearer stars are equally distributed round us, and only distant ones can show a condensation toward the Milky Way, it follows that among the distant stars are some of the brightest in the heavens, a fact which we have already shown to follow from other considerations.

Very remarkable is the fact, pointed out first by Sir J. Herschel and heavens very nearly in a great circle, but not exactly in the Milky Way. heavens very nearly in a great circle, but not exactly in the Milky Way. In the northern heavens the brightest stars in Orion, Taurus, Cassiopeia, being near the Southern Cross and the other in Cassiopeia. This belt includes the brightest stars in a number of constellations, from Canis Major through the southern region of the heavens and back to Scorpius. In the northern heavens the brightest stars in Orion, Taurus, Cassiopeia, Cygnus and Lyra belong to this belt. It would not be safe, however, to assume that the existence of this belt results from anything but the chance distribution of the few bright stars which form it. In order to reach a definite conclusion bearing on the structure of the heavens,

it is advisable to consider the distribution of the lucid stars as a whole.

Dr. Gould finds that the stars brighter than the fourth magnitude are arranged more symmetrically relatively to the bright stars we have just described than to the galactic circle. This and other facts suggested to him the existence of a small cluster within which our sun is eccentrically situated and which is itself not far from the middle plane of the galaxy. This cluster appears to be of a flattened shape and to consist of somewhat more than 400 stars of magnitudes ranging from

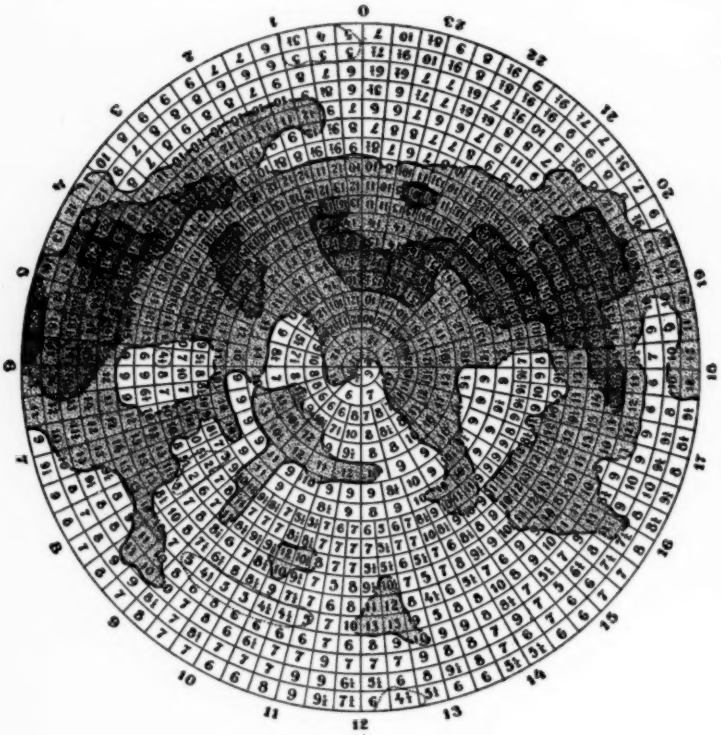

FIG. 4. NORTHERN HEMISPHERE.

the first to the seventh. Since Gould wrote, the extreme inequality in the intrinsic brightness of the stars has been brought to light and seems to weaken the basis of his conclusion on this particular point.

A very thorough study of the subject, but without considering the galaxy, has also been made by Schiaparelli. The work is based on the photometric measures of Pickering and the *Uranometria Argentina* of Gould. One of its valuable features is a series of planispheres, showing in a visible form the star density in every region of the heavens for stars of various magnitudes. We reproduce in a condensed form two of

these planispheres. They were constructed by Schiaparelli in the following way: The entire sky was divided into 36 zones by parallels of declination 5° apart. Each zone was divided into spherical trapezia by hour-circles taken at intervals of 5° from the equator up to 50° of north or south declination; of 10° from 50 to 60; of 15° from 60 to 80; of 45° from 80 to 85, while the circle within 5° of the pole was taken as a single region. In this way 1,800 areas, not excessively different from each other, were formed.

The star density, as it actually is, might be indicated by the number

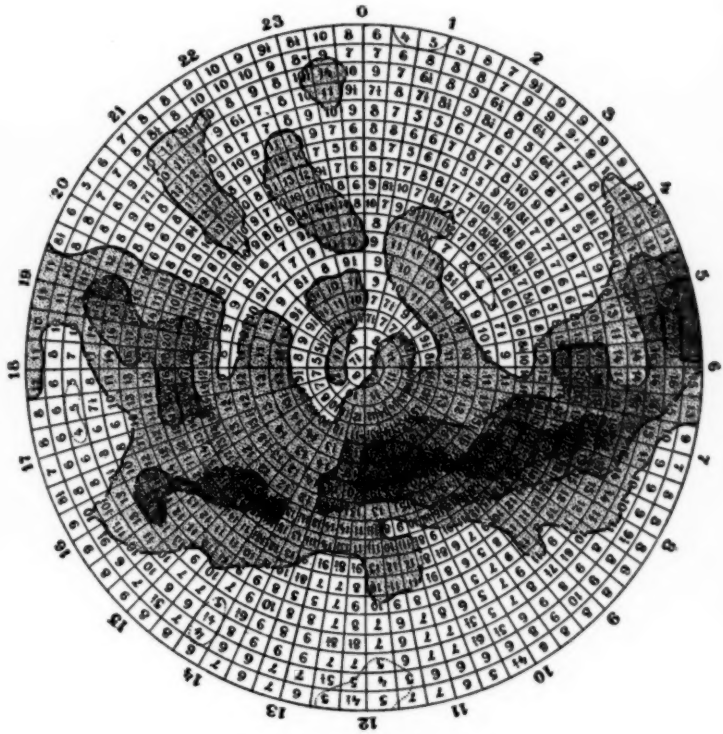

FIG. 5. SOUTHERN HEMISPHERE.

of stars of these regions. As a matter of fact, however, the density obtained in this way would vary too rapidly from one area to the adjoining one, owing to the accidental irregularities of distribution of the stars. An adjustment was, therefore, made by finding in the case of each area the number of stars contained in 1/200 of the entire sphere, including the region itself and those immediately round it. The number thus obtained was considered as giving the density for the central region. The total number of stars being 4,303, the mean number in 1/200 of the whole sphere is 21.5, and the mean in each area is 10.4.

The numbers on the planisphere given in each area thus express the star density of the region, or the number of stars per 100 square degrees, expressed generally to the nearest unit, the half unit being sometimes added.

A study of the reproduction which we give will show how fairly well the Milky Way may be traced out round the sky by the tendency of those stars visible to the naked eye to agglomerate near its course. In other words, were the cloud forms which make up the Milky Way invisible to us, we should still be able to mark out its course by the condensation of the stars. As a matter of interest, I have traced out the central line of the shaded portions of the planispheres as if they were the galaxy itself. The nearest great circle to the course of this line was then found to have its pole in the following position:

R. A.; 12h. 18m.

Dec. + 27°.

This estimate was made without having at the time any recollection of the position of the galaxy given by other authorities. Compared with the positions given in the last chapter by Gould and Seeliger, it will be seen that the deviation is only 5° in right ascension, while the declinations are almost exactly similar. We infer that the circle of condensation found in this way makes an angle with the galaxy of less than 5°.

DISTRIBUTION OF THE FAINTER STARS.

The most thorough study of the distribution of the great mass of stars relative to the galactic plane has been made by Seeliger in a series of papers presented to the Munich Academy from 1884 to 1898. The data on which they are based are the following:

1. The Bonner *Durchmusterung* of Argelander and Schönfeld, described in our third chapter. These two works included under this title are supposed to include all the stars to the ninth magnitude, from the north pole to 24° of south declination. But there are some inconsistencies in the limit of magnitude which we shall hereafter mention.

2. The 'star gauges' of the two Herschels. These consisted simply in counts of the number of stars visible in the field of view of the telescope when the latter was directed toward various regions of the sky. Sir William Herschel's gauges were partly published in the 'Philosophical Transactions.' A number of unpublished ones were found among his papers by Holden and printed in the publications of the Washburn Observatory, Vol. II. The younger Herschel, during his expedition to the Cape of Good Hope, continued the work in those southern regions of the sky which could not be seen in England.

3. A count of the stars by Celoria, of Milan, in a zone from the equator to 6° Dec., extended round the heavens.

From what has been said the question which will first occupy our attention is that of the distribution of the stars with reference to the galactic plane, or rather, the great circle forming the central line of the Milky Way.

The whole sky is divided by Seeliger into nine zones or regions, each 20° in breadth, by small circles parallel to the galactic circle. Region I. is a circle of 20° radius, whose center is the galactic pole. Round this central circle is a zone 20° in breadth, called Zone II. Continuing the division, it will be seen that Zone V. is the central one of the Milky Way, extending 10° on each side of the galactic circle.

The condensed result of the work is shown in the following table:

Column 'Area' shows the number of square degrees in each region, so far as included in the survey. It will be remarked that the catalogues in question do not include the whole sky, as they stop at 24° S. Dec.

Column 'Stars' shows the number of stars to magnitude 9.0 found in each area.

Column 'Density' is the quotient of the number of stars by the area, and is, therefore, the mean number of stars per square degree in each region. In column 'D' these numbers are corrected, for certain anomalies in the magnitudes given by the catalogues, so as to reduce them to a common standard.

Region.	Area. Degrees.	Stars.	Density.	D.
I.	1,398.7	4,277	3.06	2.78
II.	3,146.9	10,185	3.24	3.03
III.	5,126.6	19,488	3.80	3.54
IV.	4,589.8	24,492	5.34	5.32
V.	4,519.5	33,267	7.36	8.17
VI.	3,971.5	23,580	5.94	6.07
VII.	2,954.4	11,790	3.99	3.71
VIII.	1,790.6	6,375	3.56	3.21
IX.	468.2	1,644	3.51	3.14

A study of the last two columns is decisive of one of the fundamental questions already raised. The star density in the several regions increases continuously from each pole (regions I. and V.) to the galaxy itself. If the latter were a simple ring of stars surrounding a spherical system of stars, the star density would be about the same in regions I., II. and III., and also in VII., VIII. and IX., but would suddenly increase in IV. and VI. as the boundary of the ring was approached. Instead of such being the case, the numbers 2.78, 3.03 and 3.54 in the north, and 3.14, 3.21 and 3.71 in the south, show a progressive increase from the galactic pole to the galaxy itself.

The conclusion to be drawn is a fundamental one. The universe, or, at least, the denser portions of it, is really flattened between the

galactic poles, as supposed by Herschel and Struve. In the language of Seeliger: "The Milky Way is no merely local phenomenon, but is closely connected with the entire constitution of our stellar system."

This conclusion is strengthened by a study of the data given by Celoria. It will be remarked that the zone counted by this astronomer cuts the Milky Way diagonally at an angle of about 62°, and, therefore, does not take in either of its poles. Consequently, regions I. and IX. are both left out. For the remaining seven regions the results are shown as follows: We show first the area, in square degrees, of each of the regions, II. to VII., included in Celoria's zone. Then follows in the next column the number of stars counted by Celoria, and, in the third, the number enumerated in the *Durchmusterung* in these portions of each region. The quotients show the star-density, or the mean number of stars per square degree, recorded by each authority:

	Area.	Number of Stars.		Star-Density.	
Region.	Degrees.	Cel.	D. M.	Cel.	D. M.
II.	404.4	27,352	1,230	67.6	3.04
III.	284.6	22,551	932	79.3	3.28
IV.	254.6	29,469	1,488	115.7	5.83
V.	284.6	41,820	1,833	146.9	6.44
VI.	284.6	31,706	1,472	111.4	5.22
VII.	329.5	25,618	1,342	77.7	4.07
VIII.	314.5	22,264	1,184	70.8	3.77

It will be seen that the law of increasing star-density from near the galactic pole to the galaxy itself is of the same general character in the two cases. The number of stars counted by Celoria is generally between 18 and 25 times the number in the *Durchmusterung*.

An important point to be attended to hereafter is that the star-density of the Milky Way itself, as derived from each authority, is between two and three times that near the galactic poles. Very different is the result derived from the Herschelian gauges, which is this:

Region	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Density	107	154	281	560	2019	672	261	154	111

From the gauges of the Herschels it follows that the galactic star-density is nearly 20 times that of the galactic poles. At these poles the Herschels counted about 50 per cent. more stars than Celoria. In the galaxy itself they counted 14 for every one by Celoria. The principal cause of this discrepancy is the want of uniformity of the magnitudes.

The recent comparisons of the *Durchmusterung* with the heavens, mostly made since Seeliger worked out the results we have given, show that the limit of magnitude to which this list extends is far from uniform, and varies with the star-density. In regions poor in stars, all of the latter to the tenth magnitude are listed; in the richer regions of the galaxy the list stops, we may suppose, with the ninth magnitude, or

even brighter. Yet, in all cases, the faintest stars listed are classed as of magnitude 9.5. Thus a ninth magnitude star in the galaxy, according to the *Durchmusterung*, is very different from one of this magnitude elsewhere.

DISTRIBUTION OF THE STARS HAVING A PROPER MOTION.

Having found that the stars of every magnitude show a tendency to crowd toward the region of the Milky Way, the question arises whether this is true of those stars which have a sensible proper motion. Kapteyn has examined this question in the case of the Bradley stars. His conclusion is that those having a considerable proper motion, say more than 10″ per century, are nearly equally distributed over the sky, but that when we include those having a small proper motion, we see a continually increasing tendency to crowd toward the galactic plane.

But the irregularity in the distribution of the stars observed by Bradley seems to me to render this result quite unreliable. For every such star Auwers derived a proper motion. And, if these proper motions are considered, their distribution will be the same as that of the stars. To reach a more definite conclusion, we must base our work on lists of proper motions, which are as nearly complete within their limits as it is possible to make them. Such lists have been made by Auwers and Boss, their work being based on their observations of zones of stars for the catalogue of the *Astronomische Gesellschaft*. The zone observed by Auwers was that between 15° and 20° in N. Dec.; while Boss's was between 1° and 5°. To speak more exactly, the limits were from 14° 50′ to 20° 10′ and 0° 50′ to 5° 10′, each zone of observation overlapping 10′ on the adjoining one. Thus the actual breadths were 5° 20′ and 4° 20′. Within these respective limits, Auwers, by a comparison with previous observations, found 1,300 stars having an appreciable proper motion, and Boss 295. But Boss's list is confined to stars having a motion of at least 10″; of such the list of Auwers contains 431. The number of square degrees in the two zones is 1,556 and 1,830, respectively. The corresponding number of stars with proper motions extending 10″ is, for each 100 square degrees:

In Boss's zone, 18.9.
In Auwers's zone, 23.9.

The question whether the greater richness of nearly 25 per cent. in Auwers's zone is real is one on which it is not easy to give a conclusive answer. The probability, however, seems to be that it is mainly due to the greater richness of the material on which Auwers's proper motions are based. The question is not, however, essential in the present discussion.

We now examine the question of the respective richness of proper motion stars in this way:

Each of these zones cuts the galaxy at a considerable angle. Each zone, as a matter of course, has a far larger richness of stars per unit of surface in the galactic region than in the remaining region. We, therefore, divide each zone in four strips, two including the galactic regions and two the intermediate region. The boundaries are somewhat indefinite; we have fixed them by the richness of the total number of stars. For the galactic strips we take in Boss's zone the strip between 5h. and 8h. of R. A. and that between 17h. and 20h. Each of these strips being 3h. in length, the two together comprise one-quarter the total surface of the zone. If the proper motion stars crowd towards the galaxy like others do, then the numbers in the galactic region should be proportional to the total number observed in the region. But if they are equally distributed then there should be only one-quarter as many in the galactic region as in the other regions.

In the case of Boss's zone, the total number of stars observed and of those having a proper motion found in the four regions described are as follows:

	Total Number Observed.	Proper Motions. Actual.	Prop.
Galactic strip, 5h. to 8h.....	1,614	24	37
Galactic strip, 17h. to 20h.....	1,340	36	37
Intermediate strip, 8h. to 17h....	2,458	124	111
Intermediate strip, 20h. to 5h....	2,831	111	111

The last column contains the number of proper motions we should find if the whole 295 were distributed proportionally to the areas of the several strips. There is evidently no excess of richness in the galactic strips, but rather a deficiency in the strip near 6h., which is accidental.

In the case of Auwers's zone, the galactic strips are those between 5h. and 8h., and again between 18h. and 21h. Here, as in the other case, the galactic strips include one-quarter of the whole area. But, owing to the greater richness of the sky, they include nearly 40 per cent. of the whole number of stars. Then, if the proper motion stars are equally distributed, one-quarter should be found in the region, and if they are proportional to the number of stars observed, 40 per cent. should be within this region. Grouping the regions outside the galaxy together, as we need not distinguish between them, the result is as follows:

	Stars Observed.	Proper Motions. Actual.	Prop.
Galactic strip, 5″ to 8″.....	1,797	155	157
Galactic strip, 18″ to 21″.....	1,984	202	157
Outside the galaxy.....	6,008	901	944

We see that in the strip from 5h. to 8h. there is contained almost exactly one-eighth the whole number of proper motion stars. That is,

in this region the stars are no thicker than elsewhere. In the region from 18h. to 21h. there is an excess of 45 stars having proper motions. Whether this excess is real may well be doubted. It is scarcely, if at all, greater than might be the result of accidental inequalities of distribution. Were the proper motion stars proportional to the whole number, there ought to be 240 within the strip. The actual number is 38 less than this.

It is to be remembered that Auwers's proper motions are not limited to a definite magnitude, as were Boss's, but that he looked for all stars having a sensible proper motion. The question, what proper motion would be sensible, is a somewhat indefinite one, depending very largely on the data. It may, therefore, well be that the small excess of 45 found within this strip is due to the fact that more stars were observed and investigated, and, therefore, more proper motions found. Besides this, some uncertainty may exist as to the reality of the minuter proper motions.

The conclusion is interesting and important. If we should blot out from the sky all the stars having no proper motion large enough to be detected, we should find remaining stars of all magnitudes; but they would be scattered almost uniformly over the sky, and show no tendency toward the galaxy.

From this again it follows that the stars belonging to the galaxy lie farther away than those whose proper motions can be detected.

DISCUSSION AND CORRESPONDENCE.

NEEDLESS OBSCURITY IN SCIENTIFIC PUBLICATIONS.

AFTER having called attention in a recent issue of the MONTHLY to certain circumstances leading to the retardation of science, we may now venture to discuss a few of the particular ways in which a scientific writer can perplex his brother workers. Nobody supposes that the ordinary author wishes his contribution to be regarded as a sort of 'puzzle-page,' but that is the effect often unintentionally produced. The causes of this are of diverse nature. In these days of ultra-specialization and of hurry, a specialist often inclines to address himself solely to his fellow-specialists, or to an even smaller circle—his fellow-specialists of the moment, forgetting those that may come at a later day. There may be in the whole world but two men who will take the trouble to read his paper, or who would really understand its bearings. Whether from modesty or from pride, from desire of brevity or from laziness, our specialist addresses his remarks solely to those two. The student who is not yet quite at the same level, the professor who tries to keep abreast of his subject in general, the worker who comes a few years later and sees things from an altered point of view; all these find themselves 'out of it,' and long investigations are often necessary before they can be sure of the author's meaning.

The same obscurity is achieved by those whose humility leads them to think other folk more learned than themselves, whereas, in writing scientific papers, as in lecturing, political speaking or leader-writing, one should remember the old request of the listener, 'Of course, I know; but speak to me as if I didn't know,' and the practical warning of the playwright, 'Never fog your audience.' Or it may be not so much humanity as the short-sighted egoism of the enthusiast, who assumes that his little corner must needs be known to all the world. But it is perhaps not so important for our present purpose to discuss the state of mind conducing to obscurity, as it is to point out instances.

Here is a common one. In stratigraphical geology everyone is supposed to know the names of the great systems; and if the names of their main subdivisions are less familiar, they can at all events be readily hunted up in a text-book. But there are an extraordinary number of names nowadays invented for quite small divisions, or for purely local rocks, and many of these names convey of themselves very little meaning. Is there a geologist living who can say offhand what is meant by all or even half of the following names, which are taken at random from some recent publications: Plaisancien, Schlier, Catadupa beds, Calder Limestone, Hornstein, Oberen Mergel-schichten, Feuerstein, Scaglia rosata, Knorrithone, Ferrugineus-schichten, Deer Creek Limestone, Semmeringkalke, Diceratien, Moscow shale, Lenneschiefer? The language or the locality may guide one to a rough determination, or a few names of fossils may be an indication to the expert; but when these names are introduced without further explanation, as is actually the case in many of the papers from which these instances are quoted, then perplexity followed by irritation is the natural result. The names just cited are of diverse nature. Calder Limestone and Lenneschiefer are terms of local application and perfectly justifiable; all that we ask is a hint, however guarded, as to the probable horizon of these restricted rocks in comparison with a better known geological

series. Plaisancien and Diceratien are minor divisions on the time-scale, which are doubtless familiar enough to the students of Pliocene or of Middle Jurassic rocks, but which may cause the ordinary geologist a journey to the public library and prolonged search. Feuerstein and Oberen Mergel-schichten are terms the meaning of which is absolutely governed by the context, or by the place in which the author happens to live; stratigraphically considered, there can be no value in such words as firestone and upper marl-beds. As for Knorrithone, it is simply a vulgar barbarism, the offspring of specialism and illiteracy, which may do well enough for the notebook of a field-geologist, but is out of place in the official publication from which it is culled. A couple of friends may talk of the 'Bel. quad. beds' or the 'corang zone,' but a sense of respect for their science, no less than a feeling for foreign readers, should keep these colloquialisms out of their serious publications.

Akin to the instance last mentioned is the slovenly habit indulged in by many zoologists of referring to a species by its trivial name alone, without mentioning the generic name, which is an equally essential component of the name of the species. This is especially a custom with entomologists of the baser sort, who, in matters nomenclatorial, seem to be capable of anything. With them as with other classes of naturalists, this apparent familiarity is probably due to their ignorance that the same has been applied to species of, it may be, twenty other genera. They would be less prone to the habit if they knew that zoologists of wider knowledge regard it as the hall-mark of provincialism.

What is true of geological formations and of species applies also to genera. Until the reform proposed by Prof. A. L. Herrera is adopted, the scientific names of animals and plants will not be self-explanatory. How many scientific men, asks the ingenious Mexican, outside the system-artists of the group, understand what is meant by *Spinolis zena*? Is it a mushroom, an ant, a rose, a spider or a monkey? Some names are intended to indicate the class to which the plant or animal belongs; thus a name ending in *crinus* is pretty sure to belong to a crinoid, one ending in *ceras* may be a fossil mollusc belonging to the Ammonoidea; *graptus* is fairly certain to be a graptolite, and *saurus* a fossil reptile. The principle might well be extended, and systematists should at least refrain from applying a termination tacitly ear-marked for a particular group to a new genus belonging to another group. If the name of an Echinoderm genus ends in *cystis*, the reader naturally supposes that the animal belongs to the extinct class Cystidea, and he is not a little disturbed if he discovers that it is a recent sea-urchin. However, these things are so, and will continue to be so, until people realize the responsibility that rests on the proposer of a new name. It is unnecessary to do more than recall the fact that, owing to inadvertence or ignorance, the same name has often been applied to more than one kind of organism, and may for years continue to be used in both senses, while many names well-known in zoology occur also in botanical nomenclature.

The point we would emphasize is this: Considering the difficulties that inevitably spring from such a state of affairs, it is the more incumbent on writers to explain the nature or systematic position of the organism about which they are writing. Merely to give the name, even if it chance to be correct and elsewhere unappropriated, is not enough. Still less is this satisfactory when the name has been used in more than one sense. How often does a zoologist spend time and trouble in looking up a paper on some genus in which he believes himself to be interested, only to find that the subject of the article is some different animal, or even a plant, bearing the same name. To show how real a grievance this may be, let us give

an actual case. Last year two naturalists presented to the French Academy of Sciences an account of their investigations into the perivisceral fluid of *Phymosoma*. The mention of perivisceral fluid indicates that *Phymosoma* is an animal and that it possesses viscera; also that it is not a fossil. But neither the title nor the paper itself gives any further hint as to the zoological position of the creature. We must, therefore, have recourse to some work of reference, such as Scudder's 'Nomenclator,' and here we find *Phymosoma* given as the name of a sea-urchin, better known as *Cyphosoma*. This may be the reason why the paper in question has been indexed in a well-known bibliography under the head of Echinoderms. But on inquiring further into the matter we find, first, that the sea-urchin *Phymosoma* is only known as a fossil, or if it does occur in the recent state, it is by no means so common as readily to afford material for biological investigation; secondly, that the phenomena observed are not such as we have hitherto been taught to associate with the Echinoidea. These considerations, while not excluding the possibility that the *Phymosoma* of the paper is a sea-urchin, arouse our suspicion. But what is to be done? We ransack the works of reference in a great library, we appeal to our zoological friends, specialists in various branches, professors, bibliographers. In vain. The resources of civilization appear exhausted, and we . . . 'Why on earth don't you write to the authors?' says some superior practical person. My dear sir, are you not aware that the address of a scientific writer is never affixed to his publications, that if he is a Frenchman with a common name his initials are invariably replaced by M., and that, with all respect to Messrs. Cassino, Friedländer and other benefactors of scientific humanity, it is still as difficult to hunt down a budding author as to solve any other problem of scientific nomenclature? Before risking a letter that, even should it arrive, may elicit no reply, it occurs to us that the authors, being French, are likely to follow the names used by Prof. Edmond Perrier in his large 'Traité de zoologie.' Unfortunately this work, since it is still in progress, has as yet no index. However, by dint of wading through the probable groups of animals, we are at last rewarded by finding *Phymosoma* among the Gephyreans. No doubt a specialist on that small section of the worms will think all this fuss highly absurd, for the name *Phymosoma* is naturally quite familiar to him. So much the worse, since no Gephyrean has a right to it. True it is that A. de Quatrefages, in 1865, obscurely printed the name *Phymosomum* (not *Phymosoma*), as applicable to a subgenus of the Gephyrean *Sipunculus;* but the name *Phymosoma* was proposed for the sea-urchin by d'Archiac and Haime, in 1853. If both names be objected to on the score of etymology, and the more correct form *Phymatosoma* be suggested, confusion is certain to arise with a name given to a beetle in 1831 by Laporte and Brullé, viz., *Phymatisoma*, which is, in fact, though erroneously, frequently written *Phymatosoma*. At every turn, then, there is risk of that very confusion which it is the object of scientific nomenclature to eliminate.

Now it is distinctly to be understood that this narration has not exaggerated the facts one jot, and it is clear that the experience may have been shared by many others. All this loss of time, vexation of spirit and promulgation of actual error might have been spared by the insertion of the single word 'Gephyréen' in the title, or, at least, by some intimation in the paper itself. Justly then do we stigmatize heedlessness in such matters as an agent in the retardation of science.

AN EDITOR.

SCIENTIFIC LITERATURE.

BOTANY AND AGRICULTURE.

THE second volume of the 'Cyclopedia of American Horticulture,' edited by Prof. L. H. Bailey, has made its appearance from the press of the Macmillan Company and shows the same general excellence attributed to the first volume already noticed in this magazine. Subjects under the initials E. M. are treated in the last volume. Among the most notable topics of broader interest are Ferns, Horticulture, Greenhouses and the zonal regions in the various States discussed. A biographical sketch of Asa Gray, by Professor Bailey, carries with it a touch of interest due to the acquaintance of the editor with that eminent botanist. By the most recent census it has been shown that nearly 2,500 species of native American plants have been brought into cultivation. Dr. Wilhelm Miller gives a piquant description of the manner in which the Cyclopedia was written and edited in an article in the 'Asa Gray Bulletin' for August, 1900, of which the following paragraph is fairly characteristic: "The rest is hard work, and every man to his own method. Professor Bailey uses any or all methods, or no method; usually the latter. He is too busy getting done to think about the best way. Allamanda he wrote in sixty minutes by the clock. It is an article of about 640 words, with eight good species, and accounts for ten trade names. The plants are not merely described; they are distinguished. Eleven pictures were cited. Not less than twenty books were consulted. Four dried specimens were named. This was the first genus he tackled."

A MUCH-NEEDED introduction to vegetable physiology (J. & A. Churchill), by Dr. Reynolds Green, of the Pharmaceutical Society of Great Britain, has just appeared. The author discusses the general anatomy of the plant and takes up the general principles of physiology in a very attractive manner, although in certain sections the conciseness of the elementary text is not adhered to. It is a readable book, and the author is particularly apt in his sections dealing with respiration and fermentation. It is distracting, however, to find Professor Green in disagreement with himself concerning the dialysation of the enzymes, a group of substances which have been the subject of important investigations by Professor Green for a number of years. This book will undoubtedly find its way into every botanist's library in a few years.

THE annual report of the State Geologist of New Jersey, for 1899, upon Forests is a carefully indexed volume of 328 pages (State Printers), with 31 plates and some text figures. The report is in four principal divisions. C. C. Vermeule gives a general description of the forested area and the conditions of the timber in the several natural divisions of the State, which is well set forth by the aid of well-colored maps. Prof. Arthur Hollick treats the relation between forestry and geology in New Jersey and divides the State into three zones; that of deciduous trees, that of coniferous trees and an intermediate formation. Attention is also paid to the evolution of the species of trees as exhibited by fossil specimens. Prof. J. B. Smith discusses the rôle of insects in the forest. Dr. John Gifford reports on the forestal conditions and silvicultural prospects of the coastal plain of New Jersey. These, with other matter

given by the State Geologist, John C. Smock, form a splendid volume of very great practical value as well as of scientific interest.

THREE important bulletins (Reports Nos. 5, 7 and 11) of the U. S. Dept. of Agriculture, dealing with the investigations upon vegetable fibers, have been recently mailed to correspondents. It is notable that comparatively slow progress has been made in the perfection of methods of cultivation and use of new fiber plants. The time seems at hand for the making of extended and serious attempts to utilize the fiber furnished by ramie and other plants, and the importance of adding a staple of this kind to the products of the country would justify any reasonable expenditure of time and experimentation.

THE indexes and bibliographies which are being issued by the United States Department of Agriculture are among the most complete and comprehensive in the fields which they cover, and will be found helpful to persons who are pursuing studies in the various branches of science related to agriculture. The latest contribution in this line is an 'Index to Literature relative to Animal Industry,' prepared by Mr. George F. Thompson. The volume covers the publications issued by the Department of Agriculture from its establishment in 1837 to 1898, and comprises 676 pages, with some 80,000 entries. It includes a wide range of subjects, relating to the care and management of domestic animals, diseases and their treatment, statistics of different kinds of live stock, and investigations upon animal products such as milk, butter, cheese, eggs, wool, meats, etc. In these lines it renders available for convenient reference a large amount of scientific investigation, much of it unsurpassed in its line, which is so scattered through various bulletins and reports as to be easily lost sight of, and difficult for one unfamiliar with the publications of the Department to bring together.

NEUROLOGY, PSYCHOLOGY AND EDUCATION.

THE eighth volume of the 'Science Series,' edited by Professor J. McKeen Cattell and published by the Putnams, is Professor Jacques Loeb's 'Comparative Physiology of the Brain and Comparative Psychology.' The author is known as an able investigator of the physiology of the invertebrates and a thinker of daring genius. His book is in no sense a mere compend; it has the life and vigor natural to a student's presentation of his own research and theories. Professor Loeb's aim is to analyze the behavior of animals, roughly attributed to the nervous system, into elements, and to seek the definite factors that account for these elementary reactions; to replace the various hypothetical accounts of the nervous mechanism by the theory that it is a complex of a number of largely independent segmental organs; and to pave the way for an explanation of nervous action by definite laws of physical and chemical change. The book is thus an important example of the present attempts of students of life-processes to reduce physiology to the more elementary sciences of matter.

IN 'Fact and Fable in Psychology' (Houghton, Mifflin & Co.), Professor Joseph Jastrow reprints with some alterations a number of essays. The author is eminent among psychologists for his original research, and his clearness and skill in exposition are already known to readers of the POPULAR SCIENCE MONTHLY, in which most of these essays originally appeared. His wide knowledge and clear judgment fit him admirably to treat the rather delicate subjects with which his book is concerned, namely, that group of facts which arise in our minds at the word 'occult,' matters which have received such diverse treatment by both psychologists and laymen. They are directly dealt with in the essays on 'The modern occult,' 'The problems of psychical research,' 'The logic of mental teleg-

raphy' and 'The psychology of spiritualism,' while those entitled 'The psychology of deception,' 'Hypnotism and its antecedents,' 'The natural history of analogy,' 'The mind's eye' and 'A study of involuntary movements' throw light upon the general characteristics of the phenomena involved and the mental attitudes which people take toward them. The information given about the means taken by those whose interest it is to mislead observation, about the inevitable influence of our previous experiences, our temporary frame of mind and the 'unconscious logic of our hopes and fears' on our sensations and judgments, and about the tendency to make unconsciously expressive movements, is scientifically valuable, and is attractively set forth. The attitude taken toward Christian science, spiritualism, thought-transference and veridical hallucinations is, as would be expected, sane and consistent. There is, too, a pleasing courtesy and absence of any pharisaical air of superiority in the criticisms. It is Professor Jastrow's good fortune to possess, in addition to the knowledge of the criteria of evidence and inference in human phenomena proper to a scientific psychologist, an insight into the interests and motives of men outside his own class. This makes his comments on the types of interest in psychical research and the factors predisposing to belief in thought-transference or in spiritualism of especial value. There is a growing class, at least among psychologists, who have been so affected by the quantity of talk about psychical research and the quality of the work done in it, as to be fairly careless whether there be spirit communication or no, whether the adepts of spiritualism be knaves or fools or neither or both. Even to these Professor Jastrow's shrewd comments on the raison d'être of the belief will be interesting.

BARRING some traces of a too Wordsworthian sentimentalism, nothing but praise can be bestowed upon Professor MacCunn's new volume, 'The Making of Character' (Macmillan). Pedagogy, even if it can be dignified by the name of science, has suffered sadly at the hands of its friends. Loose, unsystematic, fallacious and frothy books abound; screaming too often takes the place of close reasoning, wishy-washy guessing of sober investigation. A mere enumeration of MacCunn's main divisions shows how far he has advanced beyond this. His treatment falls into four principal parts, dealing with Congenital Endowment, its nature and treatment; Educative Influences; Sound Judgment; Self-development and Self-control. As is to be expected from one of British training and associations, the social aspects of the theme are reviewed most successfully. The English distaste for psychology in its modern developments limits the discussion of congenital endowment somewhat obviously. But, take it for all in all, a wiser handbook for parents and teachers, or a more inspiring and sensible *vade mecum* for the general reader would be hard to find. Incidentally, the discussion throws some little light on the old question as to the relative educational value of the 'humanities' and the 'sciences'; but only incidentally.

THE PROGRESS OF SCIENCE.

WE again direct attention to the bills before Congress for the establishment of the National Standardizing Bureau, the functions of which shall consist in the custody of the standards used in scientific investigations, engineering and commerce; the construction, when necessary, of such standards, their multiples and submultiples; the testing and calibration of such standards and standard measuring apparatus; the solution of problems arising in connection with standards and the determination of physical constants and the properties of materials, when such data are of great importance and are not to be obtained of sufficient accuracy elsewhere. The establishment of a National Physical Laboratory has been under discussion in this country for almost twenty years, and although the urgent need of such an institution has been generally recognized, the spasmodic efforts in that direction have heretofore either lacked sufficient support from those most vitally concerned or have not taken into account existing conditions. The bill submitted last spring by the Secretary of the Treasury was evidently framed after most careful consideration of the question from its legislative as well as from its scientific and technical aspects. It is believed that its scope is as broad as could be reasonably expected at present, even by the scientific interests, and while the bureau is to be placed under a director having, as is proper, full control of its administration, there is also provided a board of visitors, consisting of five members prominent in the various interests involved, and not in the employ of the Government, the board serving thus in a supervisory capacity, and at the same time eliminating by its high standing, and by its close relationship to the technical and scientific bodies of the country, the effect of 'political influence' in the administration of the bureau.

THE prospects for favorable action by Congress seem most promising owing to the hearty cooperation of all interested, the measure having received the indorsement of the National Academy of Sciences, the American Association for the Advancement of Science, the American Physical Society, the American Chemical Society, the American Institute of Electrical Engineers, the Congress of American Physicians and Surgeons, the National Electric Light Association and other prominent organizations. It has also been indorsed by the scientific and technical bureaus of the Government, by institutions of higher learning through members of their scientific and engineering faculties, and by manufacturers of scientific apparatus, and it has appealed especially to the electrical fraternity. Although introduced towards the close of the last session, the bill was favorably reported to the House by the unanimous vote of the Committee on Coinage, Weights and Measures. The Senate bill is now before the Committee on Commerce, which, it is hoped, will repeat the action of the House Committee. The immediate passage of the measure cannot be too strongly urged, even with due regard to the great volume of other important business awaiting action during the present short session, especially as the bill could be disposed of in a very short time, containing, as it does, nothing which could possibly provoke partisan discussion.

THE importance of the National Physical Laboratory is now universally recognized. Germany attributes its won-

derful strides in the manufacture and export of scientific apparatus principally to the splendid work of the Imperial Physico-Technical Institute. The recognition of this fact on the part of English manufacturers was one of the most potent influences which last year induced Parliament to provide for the establishment of a similar bureau. Russia, about to adopt the metric system, has also established a Central Chamber of Weights and Measures, with Professor Mendelejeff at its head. At the International Congress of Physicists, held at Paris last summer, Professor Pellat read a paper on the National Physical Laboratory as a factor in the industrial development of a country, which created such a strong impression that a motion was unanimously passed in favor of the establishment of such institutions in all countries not already provided therewith. The United States, far in the van in so many respects, cannot afford to lag behind in a matter of such vital and universally recognized importance.

THAT the United States is now ready to take a place beside Germany in the production of scientific instruments is demonstrated by what has already been accomplished in the case of astronomy. In proof of this statement we may refer to the recently-issued catalogue from the works of Messrs. Warner & Swasey, at Cleveland, Ohio. This is a tangible witness that the United States is, in respect of the making of astronomical instruments of all sorts, quite out of the leading strings of the Old World. The work here exhibited is strictly of the first class. The instruments are, in the first place, designed so as to fit the uses to which they are to be put, not only in their general form, but also in their details. The execution of the mechanical work is also of the very highest quality. Lastly, we note the very significant fact that the designs of the instruments are, in a high degree, elegant and artistic. It is a far cry from the stone-adze of the paleolithic man to the Ferrera blade; and the evolution carries a lesson with it. Weapons and tools must first of all be fitted to their uses. Their design must be appropriate to the desired end. After the end is plainly comprehended improvements are made in the mechanical processes of manufacture. Last of all it is the desire of the artisan to become an artist—to make his work beautiful. The evolution of the weapon and of the tool follows laws which govern that of the scientific instrument also. Long centuries elapsed between the quadrants of Alexandria, Samarkand and Uraniborg, and the elegant designs of the instruments of the great observatory of Pulkowa. It seemed that almost the last word had been said when Struve and Repsold installed their joint productions in the Imperial Observatory, lavishly endowed by the Russian Emperor. It is highly significant, then, to find their work surpassed in a distant country across the ocean—in the country that hardly possessed an astronomical establishment of any sort when Pulkowa was founded. And it is gratifying and startling to note that two New England mechanics without hereditary training, advised by our own astronomers, have excelled the work of the famous house of Repsold, now in its third generation, advised and counseled, as it has been, by the most skilled astronomers of Europe.

A STUDY of the catalogue in question will show that in all respects—in general design, in detail and in artistic beauty—instruments now made in this country are superior to any made in the world. The book referred to is entirely composed of plates, showing equatorial mountings, micrometers, chronographs, transits, zenith telescopes, alt-azimuths, meridian-circles and dividing-engines made at Cleveland; and of views of observatories in various parts of the world furnished with instruments or domes from the same works. The observations made by some of the instruments referred to at the United States Naval

Observatory, at the Lick, Yerkes, Flower, Dudley and other establishments, are the best evidence of success. This book marks an epoch in the history of practical astronomy in America and has more than a passing value. A country that has produced the object-glasses of the Clarks and of Brashear, the sextant of Godfray, the zenith-telescope of Talcott, the chronograph of the Bonds, the break-circuit chronometer of Winlock, the diffraction-gratings of Rutherfurd and of Rowland, the mountings of Warner and Swasey—to say nothing of many minor inventions and devices—has already taken the highest place in one important field. Who can doubt that the next century will see a corresponding progress in other branches of astronomy? The oldest science may yet find its chief center in the youngest country.

THE annual report of the Secretary of Agriculture has come to be regarded as of special interest to men of science, inasmuch as it is devoted very largely to a résumé of the scientific investigation which is being carried on under his direction. The high appreciation which Secretary Wilson has of the economic value of investigation along lines related to agriculture is evidenced by his cordial support of such work, and the spirit of inquiry which he has inspired throughout the Department. His practical experience as a farmer and his active connection with experiment-station work before coming to the Department have made him quick to see the application of a new discovery and have enabled him in many instances to suggest new lines of inquiry. The result has been a wider appreciation of the department as an institution for research, and the securing of greatly increased financial support from Congress for its development along this line. It is now recognized by those familiar with it as being one of the largest and best equipped institutions for organized research in this country, and in the special lines in which it is engaged it occupies a leading position. Some of the newer features which Secretary Wilson mentions are experiments in plant breeding, directed toward the production of hardier orange hybrids for the Southern States and corn of earlier maturity and more resistant to drought and smut; studies of the true cause of the fermentation of tobacco in curing, which have suggested important modifications of the old method of handling; experiments in growing Sumatra tobacco in the Connecticut Valley, with the aid of shade, and the Cuban types of cigar-filler in Texas, the indications for the success of both of which are now considered very promising; the extensive preparation and testing of serums for combating hog cholera and tetanus or lockjaw, and of vaccine for the disease known as black-leg; field and laboratory studies of plants supposed to be poisonous to sheep on the Western ranges, to determine the actual causes of the heavy losses of stock, and to find remedies for poisoned animals; and the investigation of a number of the more troublesome plant diseases, among them diseases of the sugar beet, which are reported to have caused a loss of over two million dollars in California.

THE Department's policy of sending explorers to various parts of the world to search out new plants or varieties likely to prove valuable in this country has already resulted in a long list of promising introductions, including especially the Kiushu rice from Japan, which, it is believed, will insure the success of the rice industry in this country, and varieties of wheat from Russia, Hungary and Australia, which are superior in milling qualities, resistance to rust and yield. The successful introduction into California of the insect which fertilizes the flowers of the Smyrna fig, resulting the past season in the production of six tons of these figs of the highest grade of excellence, promises the development of another important industry. Among the larger

operations in the field the studies of the use and economy of irrigation waters have attracted widespread attention throughout the irrigated region, and have indicated that there is great opportunity for improvement in the methods and use of water. The result has been a great desire for an accurate and complete showing of facts, on which permanent improvement alone can be based; and wherever the investigations have been undertaken, private individuals and local authorities have lent their hearty cooperation. The preparation of 'working plans' for forest owners, to guide them in caring for and cutting off their forests in a more systematic manner, has proved so popular that the demands last year exceeded the resources of the Division of Forestry. Requests for these plans cover over fifty million acres of forest, and come from private owners, large consumers of timber for manufacturing purposes and public custodians. The Secretary points out the encouraging fact that public interest in forestry is at present not only keener and more widespread than at any time heretofore, but 'is growing with a rapidity altogether without precedent.' Quite large increases in appropriation for these irrigation investigations and lines of forestry work are recommended, as well as for soil surveys with reference to the distribution of alkali in the West, location of tobacco soils and other questions. Cooperation with the agricultural experiment stations has now become a prominent feature of the department work, and is heartily endorsed. Congress has recognized this in recent years by giving funds for special investigations to be carried on in cooperation with the stations. This has naturally brought the Department into much closer relations with the stations, and has tended to secure greater stability for the operations of the stations and an increased measure of influence with their own constituents. Not only is such cooperation in the interests of economy, but it strengthens the efficiency of both the Department and the stations as organizations for the improvement of agriculture. As a result of the investigations made the past year of the agricultural conditions in Hawaii and Porto Rico, the Secretary recommends the establishment of experiment stations in these islands.

THE growing interest in the work of the National Department of Agriculture is evidenced by the rapidly increasing demand for its publications. Last year three hundred and twenty new publications were issued, and the number of copies printed was considerably over seven million. This was far in excess of any previous year, both in number of publications and total edition. Notwithstanding this fact, the Department was obliged to refuse many applicants for its bulletins and reports, the number of refusals being ten times more numerous than six years ago, when the total edition was only half that of the past year. In addition to these more technical publications, one hundred and eight farmers' bulletins, including reprints, were issued, aggregating two and a third million copies. This furnishes some idea of the enormous activity of the Department in the diffusion of knowledge. But with the growth of its investigations and the consequent increase of material for publication, Secretary Wilson shows that there has not been a commensurate increase in the appropriation for printing, which has now become inadequate to the prompt diffusion of the information acquired. He accordingly requests a material increase in the printing fund for another year, but he questions whether, without some change in the present system of distributing publications, it will be possible to maintain a supply equal to the demand. The distribution has been restricted in several ways within recent years, and mailing lists have been kept revised to prevent waste. In the interest of the greatest usefulness of the Department to applied science and to its constituents, the policy should, if pos-

sible, remain sufficiently liberal to provide copies to such persons as are especially interested in the publications, and make application for them. The problem is undoubtedly a perplexing one, and unless Congress makes liberal additions to the printing fund, is likely to prove more troublesome with succeeding years.

THE present organization of the Department of Agriculture is for the most part one of divisions quite independent of each other in their operations. These are not generally grouped into bureaus, as is the case in other departments of the Government, but each is responsible directly to the Secretary of Agriculture. The lines of work of different divisions very naturally overlap, and as new lines are taken up, troublesome questions arise as to their assignment. The condition is one which calls for close cooperation along the broadest lines possible, but the segregation which has resulted from the multiplication of divisions has not conduced to this. The Secretary believes that the best interests of the Department now demand aggregation, rather than segregation, and that the time has come to bring together the related lines of work. In accordance with this policy he announces the affiliation of four divisions, closely allied by the nature of their work, under the title of Office of Plant Industry, with a director in charge. How far anything like a reorganization of the Department will be carried is at present uncertain, but it is felt that the movement is in the direction of progress, and will almost inevitably be extended sooner or later. In point of location, furthermore, the scientific divisions are widely separated, the laboratories being for the most part in separate rented buildings, removed some distance from the executive offices and the library. These buildings are regarded as temporary makeshifts, and are wholly inadequate to the present needs, several of them being dwelling houses, with small, poorly-lighted rooms. The Secretary makes a strong plea for a laboratory building, and submits plans for a fire-proof structure costing approximately $200,000. He points out that the items of rent and other expenses connected with the present laboratory quarters amount to about $10,000 a year, and that the Department is far behind many State institutions in its laboratory facilities. The excellent equipment which is being brought together in these laboratories, the extensive collections and the valuable records of investigation, are jeopardized by their present location. It seems eminently fitting that the National Department of Agriculture should be provided with the very best facilities for the important and far-reaching work which it is conducting.

THE account of the extensive and varied operations of the United States Commission of Fish and Fisheries, as contained in the annual report of the Commissioner for 1900, shows a growth, as remarkable as it was unforeseen, during the three decades that have elapsed since Professor Baird was appointed "to prosecute investigations with a view of ascertaining what diminution in the number of food-fishes of the coast and the lakes of the United States has taken place, to what causes the same is due, and what protective, prohibitory or precautionary measures should be adopted." A summary by the Commissioner of the work of the different divisions of the service is followed by detailed accounts of the propagation and distribution of food-fishes, the biological investigations, the collection of statistics of the commercial fisheries, the study of the methods of the fisheries, the inspection of the fur-seal rookeries of the Pribilof Islands, and the operations of the vessels, including a narrative of the recent South Sea expedition of the *Albatross* under Mr. Agassiz. The scientific investigations conducted in the field, on the vessels and in the laboratories pertain to almost every phase of aquatic biology. Much of the biological work is naturally and necessarily addressed to practical questions connected with the economic fisheries and fish-culture,

but facilities are freely afforded for the prosecution of purely scientific studies; and it may be noted that an unusually large number of able investigators have availed themselves of the advantages which the laboratories of the Commission afford. Among the recent acts of Congress pertaining to the scientific work have been the appropriation of a liberal sum for special experiments and investigations regarding the clam and lobster; the establishment of a new marine laboratory at Beaufort, North Carolina, and the creation of the position of fish pathologist.

THE results of the early investigations by the Commission soon led to the institution of artificial propagation as the most feasible and effective form of aid that could be rendered by the Federal Government for the maintenance of the food-fish supply; and for many years fish-culture has been the leading branch of the Commission's work. Thirty-five hatching stations in twenty-five States were operated in 1900, and new hatcheries are established at nearly every session of Congress. The output of young and adult fishes reached the extraordinary number of 1,164,000,000, which represent practically all the important food and game fishes of our rivers and lakes, and several marine species, those receiving most attention being the shad, the salmons of both coasts, the various trouts, the whitefish, the wall-eyed pike, the black basses, the cod, the winter flounder and the lobster. The important feature of this work is that a very large proportion of the ova which are handled, being taken from fish that have been caught for market, would have been lost but for the Commission's efforts; in the year covered by the report, fully nine-tenths of the output were from this source. The Commission is one of the most popular of the Government bureaus, and its popularity will undoubtedly increase as the objects, methods, limitations and results of its work become more generally known.

STUDENTS of economics are familiar with the apparently far-fetched hypothesis that periods of economic crises or hard times may be related to the fluctuations of the sun-spots. There is now reason to believe that the hypothesis is not a rash guess based on some specious coincidences. Sir Norman Lockyer and Dr. W. J. S. Lockyer have investigated the connection between sun-spots and the weather, and claim, in a paper read before the Royal Society on November 22, that increased and decreased areas of the spots on the sun may be indicative of fluctuations in the heat it gives out and that the solar conditions they indicate are approximately contemporaneous with pulses of greater rainfall. The Lockyers found that when the area of spots was greatest the unknown lines of the spectra of the sun-spots were widened; when the area was least the known lines were widened. From this they infer that a maximum area of sun-spots goes with a great increase of temperature. They thus find periodic changes of solar temperature, a maximum being followed by a mean condition, and that by a minimum. The years 1881, 1886-7 and 1892, for instance, would be, according to these spectrum records, years of mean temperature condition. The fluctuations in rainfall in India, Mauritius, Egypt and elsewhere were then compared with the spectrum records. Heavy rains generally occurred in India in the year following the mean condition, that is in dates near but somewhat earlier than the maxima and minima for sun-spots. The fall of snow followed the same rule. Between these pulses of great rainfall there are periods of drought, which correspond to the intervals between the maxima and minima of solar temperature indicated by the fluctuations in the spots. All the Indian famines since 1836 have occurred in such intervals, if we assume that maxima have appeared every eleven years. The famines of 1836, 1847, 1860, 1868-69, 1880 and 1890-92 fit almost exactly with the central points or mean conditions between minima and maxima

which occurred in 1836, 1847, 1858, 1869, 1880 and 1891. So also the mean conditions between maxima and minima which came in 1852-53, 1863-64, 1874-75 and 1885-86, are very close to the famine years 1854, 1865-66, 1876-77 and 1884-85. The possibility of predicting famines in India is too obvious for comment. The present famine is, according to the Lockyers, to be explained by abnormal solar temperature. A mean temperature would, acording to precedent, have been reached in 1897 or 1898, but observations of the spectrum show that it has not even yet been reached. To the absence of the minimum condition, which should have obtained in 1899 and caused rain from the southern ocean, the present famine is due.

AMONG recent events of scientific interest we note the following: Professor W. W. Campbell has been elected director of the Lick Observatory, in the room of the late Professor James E. Keeler.—Otto H. Tittman, assistant superintendent of the United States Coast and Geodetic Survey, has been promoted to the superintendency, vacant by the resignation of Dr. Henry S. Pritchett, to accept the presidency of the Massachusetts Institute of Technology.—The vacancy caused by the death of William Saunders, for the past thirty-eight years superintendent of Experimental Gardens and Grounds, United States Department of Agriculture, has been filled by the appointment of B. T. Galloway, who in turn has been succeeded by Albert F. Woods as chief of the Division of Vegetable Physiology and Pathology.—President D. C. Gilman, of the Johns Hopkins University, has privately intimated to the trustees his intention of resigning at the close of the present academic year, which will complete twenty-five years of service since the opening of the university in 1876.—Sir William Huggins, the eminent astronomer, has succeeded Lord Lister as president of the Royal Society. The medals of the Society have been presented as follows: The Copley Medal to M. Berthelot, For. Mem. R. S., for his services to chemical science; the Rumford Medal to M. Becquerel, for his discoveries in radiation proceeding from uranium; a Royal medal to Major MacMahon, for his contributions to mathematical science; a Royal Medal to Prof. Alfred Newton, for his contributions to ornithology; the Davy Medal to Prof. Guglielmo Koerner, for his investigations on the aromatic compounds; and the Darwin Medal to Prof. Ernst Haeckel, for his work in zoology.—Lord Avebury has given the first Huxley Memorial Lecture, which the Anthropological Institute of London has established to commemorate Huxley's anthropological work.—It is proposed to found two memorials in honor of the late Miss Mary Kingsley, one a small hospital at Liverpool for the treatment of tropical diseases and one a society for the study of the natives of West Africa.—The death is announced of Dr. John Gardiner, until recently professor of biology in the University of Colorado, and of Dr. Adolf Pichler, formerly professor of geology at the University at Innsbrück, and an eminent German poet and man of letters.—Mr. D. O. Mills, of New York, has promised the University of California about $24,000, to defray the expenses of a two years' astronomical expedition from the Lick Observatory to South America or Australia, the object of which is to study the movement of stars in the line of sight.—Surgeon Major Reed and a board of experts are continuing the investigation into the propagation of yellow fever by mosquitoes, and an experimental station will be established outside Havana.—Tufts College will open at South Harpswell, Me., next summer, a small marine biological laboratory under the direction of Prof, J. S. Kingsley.